Pilot initiatives to introduce more sustainable farming practices are many in Africa, but documentation of them is scarce.

Yet signs indicate that understanding is growing among farmers, stakeholders, researchers, and policymakers that sustainable agriculture is based on a few simple principles. These principles can be adopted to local climates and soil qualities as well as to varied technological and socio-economic factors.

Conservation agriculture provides such a set of principles. It is one of the most promising ways of implementing sustainable agriculture while minimizing the environmental degradation that is all too common on the African continent.

It relies on three basic principles: 1) minimum soil disturbance or if possible, no tillage at all; 2) soil cover— permanent, if possible; and 3) crop rotation.

This book is one in a series of case studies on conservation agriculture with examples from Ghana, Zambia, Uganda, Kenya and Tanzania, published by the African Conservation Tillage Network (ACT) and the French Agricultural Research Centre for International Development (CIRAD).

ACT, a pan-African association, encourages smallholder farmers to adopt conservation agriculture practices. It involves private, public and non-government sectors: farmers, input suppliers and machinery manufacturers, researchers and extension workers—all dedicated to promoting conservation agriculture.

Financial and material support for the case studies came from the Food and Agriculture Organization of the United Nations (FAO), CIRAD, and the Regional Land Management Unit (RELMA) of the World Agroforestry Centre (ICRAF).

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Conservation agriculture as practised in Tanzania

Tanzania

Conservation agriculture as practised in Tanzania: three case studies

Richard Shetto, Marietha Owenya, editors

Arumeru District

Karatu District

Mbeya District

CONSERVATION AGRICULTURE IN AFRICA

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Contents

Preface

Pilot initiatives to introduce more sustainable farming practices are many in Africa; thorough documentation of results and lessons learned is scarce. Yet signs indicate that understanding is growing among practising farmers, stakeholders, researchers, and to a certain degree, policymakers, that sustainable agriculture bases itself on simple core principles. These principles, making use of natural processes, can respond to local climatic conditions and soil qualities as well as technological and socio-economic factors and conditions. Conservation agriculture is one of the most concrete and promising ways of implementing sustainable agriculture in practice. It relies on three basic principles: 1) minimum soil disturbance or if possible, no-tillage seeding; 2) soil cover: if possible, permanent; and 3) useful crop rotations and associations.

Across Africa, interest is growing to adapt, adopt, and apply these principles to attain agricultural performance that improves productivity and protects the environment—it sustains environmental resilience.

The French Agricultural Research Centre for International Development (CIRAD), the Food and Agriculture Organization of the United Nations (FAO), the Regional Land Management Unit in the World Agroforestry Centre (RELMA) and the African Conservation Tillage Network (ACT) have jointly facilitated this case study series to verify and document the status and effect of pilot initiatives on conservation agriculture with focus on sub-Saharan Africa. Eight case studies from five countries—Ghana, Kenya (2), Tanzania (3), Uganda, Zambia—are published in this series. A joint synthesis publication with overall results, lessons learned and recommendations for Africa is forthcoming.

It is our intent this series will be a source of information on conservation agriculture in Africa. It throws light on controversial issues such as the challenges farmers face in keeping the soil covered, in gaining access to adequate no-tillage seeding equipment, in controlling weeds, and on the challenges projects and institutions face in implementing truly participatory approaches to technology development, even as it illustrates the benefits of systems based in conservation agriculture and the enthusiasm with which many stakeholders are taking it up.

Bernard Triomphe, CIRAD
Josef Kienzle, FAO
Martin Bwalya, ACT
Soren Damgaard-Larsen, RELMA

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Only through funding from FAO and CIRAD and the main institutions behind ACT and RELMA have the studies and this publication been made possible: the German Government through the FAO CA-SARD project, the Swedish International Development Cooperation Agency (Sida), and the Global Forum for Agricultural Research (GFAR).

Thanks to the technical editing and production team—Helen van Houten with Dali Mwagore, Keta Tom, Kellen Kebaara, Conrad Mudibo—who took on the task of assisting the case study teams and the series editors in going the 'last mile' towards publication.

Case study project background and method

Bernard Triomphe, Josef Kienzle, Martin Bwalya, Soren Damgaard-Larsen

This case study presents the status of conservation agriculture in Ghana. It is one in a series of eight case studies about conservation agriculture in Africa, which were developed within the framework of a collaboration between CIRAD (French Agricultural Research Centre for International Development), FAO (Food and Agriculture Organization of the United Nations), RELMA-in-ICRAF (Regional Land Management Unit of the World Agroforestry Centre) and ACT (African Conservation Tillage Network).

This introductory section outlines the overall background of the conservation agriculture case study project and the key methodological choices made. It also gives a brief overview of major results and observations across all case studies. This broad perspective allows the reader to appreciate both the commonalities among the eight case studies and the specifics of the thee being presented here.

Conservation agriculture: a working definition

'Conservation agriculture' has been defined differently by different authors. Perhaps the most generic definition is the one provided by FAO:[1]

> *CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.*

From this definition, we can infer that conservation agriculture is not an actual technology; rather, it refers to a wide array of specific technologies that are based on applying one or more of the three main conservation agriculture principles (IIRR and ACT 2005):

- reduce the intensity of soil tillage, or suppress it altogether
- cover the soil surface adequately—if possible completely and continuously throughout the year
- diversify crop rotations

Ideally, what we call 'conservation agriculture systems' comprise a specific set of components or individual practices that, combined in a coherent, locally adapted sequence, allow these three principles to be applied simultaneously (Erenstein 2003). When such a situation is achieved consistently, we speak of 'full conservation agriculture', as illustrated by the practices of many farmers in southern Brazil (do Prado Wildner 2004; Bolliger et al. 2006) and other Latin American countries (Scopel et al. 2004; KASSA 2006).

1 FAO conservation agriculture website: http://www.fao.org/ag/ca/index.html

Full conservation agriculture, however, is today rarely practised outside South America (Ekboir 2003; Derpsh 2005; Bollinger et al. 2006), and is indeed difficult to achieve right from the onset. Usually farmers who are willing, or obliged by circumstances, to reassess their farming practices and follow the path to more sustainable agriculture, embark on a long journey that takes them several years or even longer. This journey consists of consecutive phases, each characterized by use of specific practices that increasingly incorporate practice and mastery of the three principles. No journey appears to be linear, and no journey seems to comprise the exact same sequence of phases (fig. A), although some paths are more commonly followed than others.

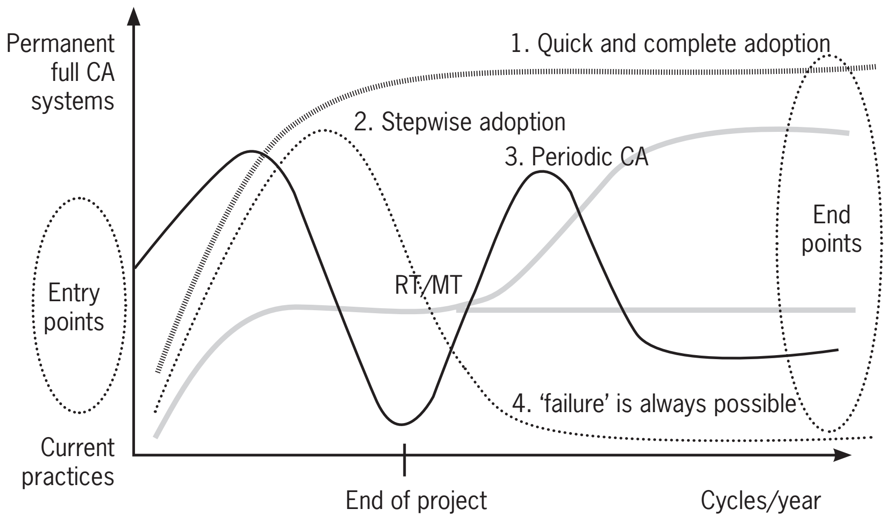

Figure A. Entry points and four hypothetical pathways towards adopting conservation agriculture:

1. Quick and complete adoption of conservation agriculture in its fullest form
2. Stepwise adoption of conservation agriculture practices, which may or may not lead to complete adoption over time (RT = reduced tillage, MT = minimum tillage)
3. Conservation agriculture practised during some cycles but not others
4. Use of conservation agriculture practices stops soon after the end of the project, perhaps because incentives are no longer available.

While the hope of many farmers and agronomists is that eventually most farmers in a given region will reach the full conservation agriculture phase, and better sooner than later, no phase in itself, no individual conservation agriculture system or set of practices can be considered intrinsically superior to the others (Triomphe et al. forthcoming).

Rather, they should be viewed as what can realistically be achieved at a given time and in a given farm context, depending on the environmental, socio-economic, institutional and political circumstances and constraints. Some factors and conditions clearly relate to the characteristics, preferences and experiences of individual farmers and farms—such as the capital available for investing in equipment and inputs, the choice of cover crops, the soil conditions prevailing at the time conservation agriculture is being introduced, the care with which a farmer applies inputs or controls weeds, or the ability to learn new practices and take risks (Erenstein 2003). Others, however, relate more to the local or regional environment of the farm: ease of access to equipment, inputs and relevant knowledge, links to markets, existence of policies favouring (or discouraging) the adoption of conservation agriculture practices, and so on.

Given this huge diversity of adoption pathways, we use the term 'conservation agriculture' in this booklet with a meaning as general and open as possible, trying to refrain from judging if some actual practices were 'real' or 'good' conservation agriculture, while others were 'partial' or 'poor'. Rather, we have made every effort to understand and explain what motivates farmers to try specific conservation agriculture practices, or what prevents them from trying the practices or from achieving success with them. At the heart of this assessment lies our desire to distinguish between conservation agriculture in theory (as promoters of conservation agriculture would like it to be implemented), and conservation agriculture in practice (as farmers are eventually able, or willing, to implement it).

Background

Why it was necessary to develop case studies

Rigorous documentation of successes, failures and challenges related to conservation agriculture adaptation and adoption is still rare, especially outside of South America. Also, most existing case studies have been written without relying on a unified systemic analytical framework, and hence are difficult to compare one with the other. They furthermore often demonstrate a strong bias towards emphasizing what is going well, overlooking process issues and problems encountered.

Under these conditions, the FAO working group on conservation agriculture and CIRAD decided to join forces in 2004 to contribute to a balanced documentation of conservation agriculture experiences and to better networking internationally. They were soon joined by RELMA-in-ICRAF and ACT, which had been actively involved in promoting conservation agriculture in eastern and southern Africa (Biamah et al. 2000; Steiner 2002; IIRR and ACT 2005) and which were also core partners in organizing the Third World Congress on Conservation Agriculture, which took place in October 2005.

Objectives

The overall objective of the conservation agriculture case study project was to strengthen collaboration among a number of key stakeholders who were preparing the Third World Congress on Conservation Agriculture, by improving understanding of past and current conservation agriculture experiences, and by improving networking among key stakeholders, with special emphasis on Africa.

Specific objectives for the case studies:

- Develop a framework for rigorously analysing ongoing conservation agriculture projects[2] and experiences and for characterizing in a holistic way

2 The word 'project' is used in this context with an inclusive meaning, as it can refer to individual ongoing projects in a region or a country, or to a succession of projects having

how conservation agriculture practices are adapted and adopted and their effect.
- Develop a number of contrasting conservation agriculture case studies by applying this framework in selected regions.

The aim was to provide the resulting outputs to conservation agriculture practitioners, scientists and decision makers, so that they could contribute to improving conservation agriculture project planning and implementation.

What does a case study entail?

Here, a case study is a short-term, mostly qualitative study that synthesizes experiences and results obtained by applying and using conservation agriculture principles and technologies in a specific region in past or ongoing efforts and projects. It is developed around a unified, locally adapted framework focusing on conservation agriculture techniques and processes, on key issues and lessons learned, as well as on shortcomings and successes.

Majors phases of the case study project

The case study project on conservation agriculture began in late 2004 (table A). Following agreement on an analytical framework in February 2005, most of the fieldwork was developed during March–September 2005 by small teams of project personnel based in the study site, with guidance from the project coordinators. Early results and preliminary products were presented at the Third World Congress on Conservation Agriculture, held in Nairobi in October 2005 (Boahen et al. 2005; Baudron et al. 2005).

In the first half of 2006, drafts of individual case studies were developed through an iterative review process. The review culminated in a workshop held in Moshi, Tanzania, in August 2006, during which case study leaders and conservation agriculture resource persons worked together to further improve the drafts and compare results among case studies. The final step in developing the case studies, during the last quarter of 2006, involved a new round of editing in interaction between a team of editors and case study leaders.

Key methodological choices

Case study framework

The framework was developed in several stages. It integrated a series of previously identified issues, such as those developed under the auspices of programmes such as the Direct Seeding, Mulching and Conservation Agriculture Global Partnership programme[3] of the Global Forum for Agricultural Research (GFAR), WOCAT[4] and Sustainet.[5] A major milestone for framework development was the workshop held in Nairobi in

taken place in one region or country over time, or to a number of projects operating simultaneously in one given region or country.

3 Website: http://agroecologie.cirad.fr/dmc/index

4 Website: http://www.wocat.org/

5 Sustainet website: http://www.sustainet.org

February 2005, which made possible direct interaction between the coordinators of the case study project and the future case study leaders.

Table A. Milestones of the case study project on conservation agriculture

Date	Product, activity, output
Late 2004	Preliminary case study selection, draft framework developed
February 2005	Start-up workshop with selected team leaders for the case studies; agreement on the framework
March–Sept 2005	Activities for developing the case studies in the various sites, including midterm reviews in Kenya, Tanzania and Ghana
October 2005	Preliminary results reported as posters, papers and oral presentation during Third World Congress on Conservation Agriculture, Nairobi, Kenya
March–July 2006	Review and revision of individual case study drafts
August 2006	Workshop on cross-analysing cases and discussing their publication
Oct–Dec 2006	Final editing of individual case study documents
Early 2007	Case studies published as books and booklets

Eventually what became the reference framework for this project, guiding case study development, was a list of questions and issues structured under six main headings (see 'Reference framework for case studies', page xxiv, for details):

- biophysical, socio-economic and institutional environment of conservation agriculture farming systems
- historical review of work related to conservation agriculture in the selected site, region or project
- specific technologies, packages or systems being promoted, and how they differ from existing practices and systems
- overview of adaptation and diffusion process towards conservation agriculture
- qualitative overview of impact and adoption, in its agronomic, economic and social dimensions
- key gaps and challenges in site-specific circumstances

Using this overall framework, each case study team selected and adapted the issues most relevant to their own conditions and circumstances. Similarly, they developed their own guidelines for interviews and workshops. Thus the actual application of the framework remained specific to each case study.

Selection of case studies

Since this project could develop only a handful of case studies at the time, it was important that criteria for selecting them be clear. They included:

- demonstrated strong local interest for participating in a case study and helping develop it, and particularly local commitment for allocating staff time and resources such as transportation and communication for related activities

- overall value the case study would add towards addressing key issues related to conservation agriculture, particularly in extracting original, worthwhile lessons on how its technologies performed, on ways they are diffused and adopted, and on links to sustainable agriculture and rural development[6]
- existence of at least a minimal body of local documentation on work related to conservation agriculture, from which a case study could be built
- complementarities with ongoing documentation efforts—preference often being given to situations for which no previous reports were available
- existence of a minimum trajectory of adaptation and diffusion, including evidence of some initial effect among farmers using conservation agriculture[7]

Based on a combination of these criteria, and following agreements reached among key stakeholders, 11 case studies were eventually selected (table B), out of which 8 were selected in Africa. More than half were directly linked to ongoing projects operating in eastern Africa.

How case studies were developed

The case studies were developed following an approach that presented a number of prominent features.

- It emphasized collaboration between insiders (local project staff) and a number of outsiders (case study coordinators and resource persons).
- It focused on a qualitative assessment of selected key issues and questions, based on participatory rural assessment techniques (interviews with key informants, collective workshops with selected stakeholders), which made it possible to collect testimonies.
- It relied on available evidence as found in project reports and documents.

Within these overall methodological choices, the specific steps and procedures followed to develop a case study included the following:

- Form a local case study team, typically comprising three to six members, usually practitioners involved in promoting local conservation agriculture.
- Develop a detailed work plan.
- Identify and collect local formal and grey literature about past or ongoing conservation agriculture activities in the region.
- Identify resource persons and institutions to serve as key informants.
- Hold interviews and workshops with key informants and stakeholders; observe conservation agriculture plots that farmers and farmer groups have implemented.
- Organize a mid-term review involving the local case study team, resource persons and project coordinators:

6 The selection of cases was, however, not limited to ‘success stories’; some of the sites experienced or still are experiencing difficulties. The important point was what useful lessons could be gained from looking at what had happened so far.

7 Since it usually takes decades before large-scale adoption occurs, few potential case study sites would have witnessed it. Hence projects were selected that were just beginning to adopt (and thus were still significantly dependent on the project), provided that the technologies were already being tested at commercial scale under farmers’ conditions.

  - Review progress, difficulties, and preliminary findings.
  - Agree on priority activities for completing the case study and on adjustments needed in the original work plan, framework or methods.
  - Identify concrete products to be presented during the Third World Congress on conservation agriculture (Nairobi, October 2005)
  - Make a number of field visits to discuss with farmers and farmer groups and observe conservation agriculture experiments and demonstrations.
- Write up the case study draft.
- Prepare and present preliminary outputs for the Third World Congress on conservation agriculture (posters, oral presentations, papers).
- Develop the case study document in interaction with external reviewers.

The results obtained within the context of each case study outline an emerging but as yet incomplete picture about conservation agriculture in a given site. The case studies are qualitative in nature and relied principally on field observation. The case study teams had only some three to five months in which to compile their information. Their access to quantitative data was often limited. At times team members found it quite difficult to separate their role of critically assessing how conservation agriculture was functioning from their normal role as promoters of conservation agriculture.

The evidence the teams uncovered, however, is a major step forward. The findings are broadly consistent with the experiences and perceptions of most stakeholders and resource persons, and as such, they provide a legitimate, unrivalled view of present successes, challenges and the way forward. The studies are furthermore quite useful in pointing out to which specific areas and issues future projects should direct their efforts.

This book focuses on three specific case studies in Tanzania. A number of results and lessons, however, can be drawn from a cross-analysis of all eight case studies selected. Such an analysis offers a unique opportunity to look at key technical and process issues and will be the focus of a separate publication.

The cross-analysis will summarize the information available to assess conservation agriculture practices implemented by farmers and their effects on crop productivity and profitability, and on labour use. It will discuss adoption trends. It will examine the approaches used to develop and promote conservation agriculture practices and systems, including the roles stakeholders, farmers' associations and the farmers themselves play in the process. It will analyse the extent to which adequate policy support is in place. In it, the following topics receive special attention. Preliminary comments follow.

First-hand observations

Tillage intensity

All types of tillage intensities are found across case studies: from minimum tillage to ripping to actual no-tillage. Most case studies highlight a number of difficulties farmers face when abandoning conventional tillage. It seems many do not go directly to no-tillage, and rely instead on reduced tillage as an intermediate step, if only because of restricted access to no-till seeders. This applies to case studies in Arumeru, Karatu, Laikipia and Zambia.

Table B. Key characteristics of case studies selected in Africa

Country, region	*Climate / type of farmers*	*Experience with CA*	*Adoption status*	*Supportive project*	*Team leader*
Kenya					
Laikipia	Semi-arid highlands / small- and large-scale, manual and animal traction	> 10 yrs (large), 2–3 years (smallholders)	Growing adoption (large), incipient (smallholders)	CA-SARD Kenya	Tom Apina, Paul Wamai, CA-SARD
Siaya	Humid lowland / small, vulnerable households, manual agriculture	3–5 years	Incipient	CA-SARD Kenya	Philip Mwangi, Kennedy Otieno, CA-SARD
Tanzania					
Karatu	Semi-arid to sub-humid, highland / manual agriculture	Late 1990s / early 2000	Incipient	CA-SARD Tanzania	Dominick Ringo, RECODA
Arumeru	Semi-arid to sub-humid, manual agriculture, highly degraded soils	Late 1990s / early 2000	Incipient	CA-SARD Tanzania	Catherine Maguzu, RECODA
Mbeya	Semi-arid / smallholders, manual and animal traction		Incipient	FAO-TCP	Saidi Mkomwa, ARI Uyole, TCP
Ghana					
Brong Ahafo, Ashanti	Rainforest transition / smallholders, purely manual agriculture	> 10–15 years	Significant but stagnant	FAO-RAFA / RELMA	Philip Boahen, consultant
Uganda					
Pallisa, Mbarara, Mbale	Humid to sub-humid / smallholders	3–5 years	Incipient	FAO-TCP	Paul Nyende, consultant
Zambia					
Southern Province	Semi-arid / smallholders, manual and animal traction	> 10 years	Large-scale, increasing adoption	CIRAD-WWF, ASP	F. Baudron, CIRAD-WWF, H. Mwanza, ASP

ASP – Agricultural Support Project (Sida funded), Zambia; CA-SARD – Conservation Agriculture for Sustainable Agriculture and Rural Development (FAO, sponsored by Germany), CIRAD – French Agricultural Research Centre for International Development; FAO – Food and Agriculture Organization of the United Nations; FAO-RAFA – FAO Regional Office for Africa; RECODA – Research, Community and Organizational Development Associates; RELMA – Regional Land Management Unit of the World Agroforestry Centre; SARI – Selian Agricultural Research Institute, Tanzania; TCP – Technical Cooperation Project (FAO sponsored); WWF – World Wide Fund for Nature

Soil cover

Providing adequate soil cover is a cornerstone of conservation agriculture. Yet most farmers face great difficulties in achieving it. Farmers tend to collect residue or allow livestock herds to graze freely on crop residue. This may be an individual decision, or it may be the result of agreements and traditions regulating the relationships between farmers and pastoralists, such as with the Maasai in northern Tanzania. Producing enough biomass to cater for both adequate soil cover and livestock demands is a challenge. Replacing a food legume used traditionally in intercropping (such as beans) by a cover crop (such as canavalia or mucuna) might not be attractive to a farmer whose primary objective is achieving food security. This may explain the success that *Dolichos lablab* is having with Kenyan and Tanzanian farmers, as it is a multiple-purpose cover crop, able to provide food (both grain and leaves are edible), income, forage and soil cover.

Weed control

Weed control remains a challenge, especially when farming is done manually. As most farmers do not manage to keep their soils adequately covered, reducing tillage tends to increase aggressive weed growth. Controlling weeds adequately, which is critical to avoid crop failure, requires hoeing numerous times[8] or using herbicides such as glyphosate. For many farm families, neither option is feasible. Labour resources are scarce or expensive, or access to herbicides and sprayers is restricted. More efforts are definitely needed to identify suitable cover crops and to achieve soil cover if herbicide dependency is deemed undesirable.

Equipment and inputs

Reduced tillage implements such as rippers and no-till seeders have been made available to farmers on an experimental basis. Often implements are imported from Brazil. Farmers are also being helped to get specific inputs, such as herbicides and cover crop seeds. Many farmers have restricted access to both implements and inputs; thus they are likely to delay planting, which adversely affects yield and income.

Family labour is increasingly scarce. This situation should ultimately lead to technologies such as reduced tillage systems, direct seeding technologies, herbicides, weed wipes or sprayers that save labour, although many farmers may not find them accessible or affordable.

Large-scale adoption of conservation agriculture practices requires a functioning input supply chain. This means both private and public sectors must play a more proactive role in developing local capacity for manufacturing and making available appropriate implements and in devising innovative implement-sharing schemes (hire services, Laikipia) and adequate rural finance systems. Empowered farmers groups are perceived as being the right entry point for making inputs and services available.

8 For example, in southern Zambia conservation agriculture promoters recommend weeding four to six times.

Overemphasis on field-scale, technical issues?

Many projects and teams tend to focus on technical issues such as tillage, cover crops, weed control and implements at the field scale. This focus often implies less attention is given to non-technical issues, for example rural finance, marketing and value chain development, organizational or policy issues.

Farmer groups

The role of government institutions and publicly funded projects is essential. Case studies in northern Tanzania and Kenya emphasize participatory approaches, in particular farmer field schools. Early indications are that these field schools are a cost-effective way of participatory training. Groups of 10–30 farmers engage in collective and individual experimentation and learn conservation agriculture principles and practices. Beyond the issue of groups, projects and institutions can potentially develop more participatory and responsive approaches, with farmers more clearly in control.

Indigenous knowledge and innovative technology

Indigenous knowledge compatible with the principles of conservation agriculture is widespread across case study sites. Such is the case for the 'proka' slash-and-mulch system in Ghana, and for the farmers who are knowledgeable about the benefits of cereal–legume intercrops.

Ongoing projects tend to undervalue indigenous knowledge. One reason may be that conservation agriculture champions are keen to transfer external knowledge and innovative technology packages as a means of replicating the success stories that evolved in southern Brazil over a period of decades. Another reason is the tendency to perceive more the negatives of local traditions and farmer practices, such as grazing rules, without trying to understand the reasons for them. Tapping into indigenous knowledge and farmer innovation combined with imported innovative technology could well prove important in the long run.

♦ ♦ ♦ ♦ ♦

This booklet now focuses on the situation of conservation agriculture in Arumeru, Karatu and Mbeya districts, Tanzania. It illustrates precisely some of the successes, and some of the challenges, that farmers and conservation agriculture projects alike face in their efforts to understand and implement conservation agriculture.

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Tanzania case study synthesis

Richard Shetto, Marietha Owenya

Agriculture is the leading sector of the economy in Tanzania, accounting for about half of both the gross domestic product and merchandise exports. Some 80% of the 34.5 million country population, especially those in rural and peri-urban areas, depend on agriculture for their livelihoods (URT 2001, 2003). Agricultural production in Tanzania is largely smallholder subsistence. Yields are generally low—for example, averaging below 1 t/ha for maize, being held back by such factors as low and generally declining soil fertility, soil and water loss through erosion, erratic and unreliable rainfall. Conventional farming practices such as burning or removing crop residue and intensive tillage often make these problems worse (Msolla et al. 1997; Kakeya et al. 1998). In many arable lands, nutrient mining is severe, with cropping activities estimated to be depleting nutrients at rates six to seven times greater than the rate at which they are being replenished.

Increasingly, farmers are pointing to soil degradation as a key issue among the factors constraining crop production (Taruvinga 1995; BACAS 1996; Temu 1996). Poor and declining farm outputs, and especially the instability in yields that even minor climatic changes bring on, virtually immediately affect food security and farm incomes adversely.

Tanzania recognizes that managing its natural resources sustainably needs to be an integral part of its agenda for agricultural productivity (URT 2001, 2003). Thus it is promoting conservation agriculture, especially in the Arusha region, as a combination of crop and crop–livestock production practices that make land more productive even as it improves the resilience of natural resources.

Conservation agriculture is gaining recognition as a way to farm that boosts agricultural performance.

Existing indigenous soil conservation system

The term ‘conservation agriculture’ may be new to Tanzanians, but not new to most farmers and rural communities is the concept that the land must not be allowed to degenerate while it is producing crops. Farming operations are based on this understanding. Fallowing and using organic matter are practices that farmers traditionally use to maintain or restore soil fertility. From the 1950s, government agricultural extension programmes have promoted soil and water conservation practices to control surface water runoff, such as stone and earth bunds, ridging, pitting, infiltration or cut-off drains, bench terraces and contours (Shetto and Lyimo 2001). Vegetable growers as well as coffee and banana growers in Arusha, Kagera, Kilimanjaro and Mbeya Regions commonly mulch their fields. The system in Kilimanjaro Region is known as ‘the Chagga home garden’.

Most traditional soil and water conservation practices, however, have turned out to be ineffective or simply impossible to apply. Land pressures in most cases have rendered fallowing simply impossible.

Evolution of conservation agriculture in Tanzania

Increased livestock and human activity has led to collapse of the conventional soil conservation system and increased land degradation—soils compacted, depleted of nutrients and organic matter, low in water-holding capacity and microbial activity. In the late 1980s the government initiated programmes to address the situation. Most aimed at combating land degradation through mechanical and biological measures: reforestation activities, agroforestry, protection of water catchments, improved land husbandry and environmental conservation in general (Shetto and Lyimo 2001).

Conservation agriculture recommended vs. practised by smallholders

Adoption of conservation agriculture practices has been slow, with farmers adopting certain components only, such as covering the soil by mulching. Components adopted are partly based on what farmers see as feasible in their particular circumstances. In drier areas, drought, free-range grazing and harvesting of crop residue for various uses have made soil cover difficult to maintain.

Issues such as weed control, accessibility to appropriate tools and equipment, and competition for crop residue have influenced rate and extent of adoption. Slowly, however, farmers have been integrating various components.

Weed control

These case studies reveal that weed control is a critical problem during the first two years of converting to conservation agriculture—the transition period. Soil cover in the long term helps reduce weed intensity and hence saves the energy, time and materials that would have been needed for weeding. Although herbicides are seen as a good investment and reduce labour during weeding and land preparation activities such as clearing, ploughing and burning residue, few can afford them. A litre of Round-Up costs around TZS 8500 (USD 85), while hiring labour for one acre for each weeding costs TZS 8000–10,000 (USD 80–100), with up to three weedings required. Therefore, those who can afford to apply herbicides save time and reduce costs.

Competition between soil cover and livestock feed

With the traditional system of free grazing after harvesting and lack of alternative fodder during the dry season, trying to maintain soil cover takes a real effort. Weak enforcement of environmental bylaws has worsened the situation.

Currently the types of biomass available in the villages for soil cover are crop residue (maize, sunflower), cover crops (*Dolichos lablab*, crotalaria and canavalia), dead weeds and mulch. Initially these were left for livestock (by either cut-and-carry or free grazing), fuel, thatching or fencing; therefore, the conflict is great as to whether to use the biomass to cover the soil or to feed the livestock. To promote conservation agriculture, alternative ways of feeding the livestock need to be suggested and promoted.

Unfenced fields are the most adversely affected by roaming livestock, with over 80% of the cover and residue grazed or removed. Bylaws that restrict free grazing of livestock exist but enforcement is poor.

The case studies indicate that fields intercropped with mucuna, lablab or pigeon pea are respected after the maize harvest, with neither grazing nor cut-and-carry operations carried out. However, all study districts reported that in times of need, owners of the fields themselves removed some of the cover.

Adoption

By the end of the two-year project, the number of farmer field school groups in the CA-SARD project had increased from the original 31 to 44. This means the number of farm households involved increased from about 775 to over 1200. Approximately 5000 farmers in these households, adopting through different organizations, have taken on at least one or two elements of conservation agriculture.

Although time in the trial study was too short to assess adoption, the farmers themselves could see the differences in practice, hence in output, between those practising conservation agriculture and those who did not, especially in dry years. This resulted in a large number of farmers asking to become members of farm field schools, wanting to get the technology and the implements. Some farmers did not want to wait to become members through projects. In Upendo Nyuki in Arumeru, and Tumaini and Hongera Tumaini in Karatu, farmers formed their own groups and requested technical assistance and hiring of implement services.

Effects

Conservation agriculture intervention produces both short-term and long-term effects.

Short-term benefits

- Increase in crop yield—in Mbeya maize yield increased 26–100%, sunflower by 360%; in Arumeru and Karatu the increase was 60–70%
- Less labour needed: hand-hoe planting takes 3 people a day to plant 1 acre while one person using a hand jab planter takes 3–4 hours to plant the same area
- Less labour for preparing land: in conventional agriculture operations are slashing, collecting and burning trash, and ploughing; in conservation agriculture slashing is the only operation

Long-term benefits

All case studies reported these effects:

- Soil erosion reduced: hence gullying and land degradation lessened
- Soil fertility and structure improved: also improved water-holding capacity
- High and stable yields: for example, conservation agriculture farmers in Babati went from 4 to 24 bags per acre; in the LAMP project, from 3–6 to 15–20 bags per acre and ARI-Uyole from 5–8 to 10–17 bags
- Social interaction increased

- Livelihood improved: farmers become able to purchase bicycles and their own conservation agriculture implements, modify their houses, improve education for their children, purchase dairy cattle and goats

Obstacles to overcome

Widespread adoption of conservation agriculture in Tanzania has been hampered by various factors:

- Inadequate knowledge of conservation agriculture technologies and practices among small-scale farmers and other stakeholders working to improve crops
- Crop and livestock integration packages inadequate to accommodate conservation agriculture practices
- Limited knowledge of proper equipment
- Implements such as rippers, subsoilers, direct planters not available
- Weed problem, especially in the early years of adoption

Conclusions and the way forward

To promote conservation agriculture in Tanzania the following should be considered:

- Farm- and village-level extension staff and facilitators need appropriate training and retraining.
- It is important to integrate conservation agriculture practices with practices such as contouring and agroforestry.
- Conscious efforts need to be made to establish institutions that will spread these technologies to new areas in the districts.
- Good coordination among stakeholders is essential.
- Various stakeholders (research, extension, private sector, farmer organizations, policymakers) need to be made more aware of the potential of conservation agriculture through various strategies (leaflets, seminars, news media, field days).
- Participatory approaches in implementing earmarked initiatives will promote a sense of ownership and synergy among those involved—the key to sustainability.

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Reference framework for case studies

Based on the activities developed in the early stages of the project, the following questions appeared critical for structuring the framework around which all case studies would be based. They are grouped under three overarching headings:

- **Specific technical aspects related to conservation agriculture systems**
  - What are the key obstacles, challenges and way forward for controlling weeds in conservation agriculture?
  - Under what conditions does conservation agriculture lead to saving farmers labour?
  - What are the key obstacles, challenges and way forward related to crop–livestock interaction while using and adopting conservation agriculture systems?
  - What are the key obstacles, challenges and way forward for conservation agriculture in low-rainfall (semi-arid) areas?
- **Conservation agriculture learning and adoption processes**
  - What does it take to 'learn' conservation agriculture, both individually and collectively (activities, processes, etc.)?
  - What influence does the mindset of farmers, technicians and researchers have on adapting and adopting conservation agriculture practices?
  - What are the relative roles of technology transfer and local adaptation in gaining large-scale adoption of conservation agriculture systems?
  - What are the entry points and pathways that lead to large-scale adoption of conservation agriculture? Are some more effective than others?
  - Have large-scale farmers a comparative advantage in adopting conservation agriculture? What advantages and why? Under what conditions can conservation agriculture work for smallholders and resource-poor households?
  - What are the key lessons learned in scaling up adoption? Do's and don'ts, and why.
- **Generic description of the conservation agriculture project**
  - Biophysical, socio-economic and institutional environment of conservation agriculture work.
  - Trajectory of related work in the selected region, site, project.
  - Overview of the conservation agriculture adaptation and diffusion process.
  - Conservation agriculture impact.
  - Present gaps and challenges in conservation agriculture work.

Arumeru District

Catherine W. Maguzu, Dominick Ringo, Wilfred Mariki, Marietha Owenya, Flora Kola, Charles Leseyo

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Abbreviations

AIDS	acquired immunodeficiency syndrome
AVRDC	Asian Vegetable Research Development Centre
CA	conservation agriculture
CARMATEC	Centre for Agricultural Mechanization and Rural Technology
CASARD	Conservation Agriculture for Sustainable Agriculture and Rural Development
CIMMYT	International Maize and Wheat Improvement Centre
CIRAD	Centre de Corporation International en Researche Agronomique pour le Développement
CTP	Conservation Tillage Project
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
HIV	human immunodeficiency virus
KENDAT	Kenya Network for Draught Animal Technology
NGO	non-governmental organization
PADEP	Participartory Agricultural Development and Empowerment Project
RECODA	Research, Community and Organizational Development Associates
RELMA	Regional Land Management Unit of Sida
SARI	Selian Agricultural Research Institute
SCAPA	Soil Conservation and Agroforestry Programme in Arusha
SLM	sustainable land management
TEMDO	Tanzania Engineering and Manufacturing Design Organization
TFA	Tanganyika Farmers Association
TFSC	Tanzania Farmers Service Centre Ltd
TZS	Tanzania shilling; valued at 1000 to USD 1 in this report
URT	United Republic of Tanzania
USD	United States dollar
WADEC	Women's Agriculture Development and Environmental Conservation

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Executive summary

A case study of conservation agriculture in Arumeru District was carried out to establish a conservation agriculture history and describe adapting and adopting conservation agriculture with experiences, challenges and issues in Arumeru District.

Conservation agriculture is a farming technology introduced in Arumeru District through the intervention of the government, NGOs and the private sector. Its basic principles are crop rotation, soil cover and minimum soil disturbance. These principles are geared towards improving soil fertility by improving water retention, increasing soil organic matter, and reducing soil degradation. Conservation agriculture aims to increase farm production, household food security, and income with less labour.

The information was collected through participatory methods. The sites had a previous conservation agriculture project or current conservation agriculture activities or community organization or used any conservation agriculture principle. A local case study team was formed. District stakeholders were identified by their participation and knowledge of conservation agriculture. Information was solicited from institutional reports. The case study team talked to farmers who had tried conservation agriculture and then abandoned it, farmers who practised conservation agriculture although they were not initially targeted for it, key stakeholders and agricultural officers. The district has major roads connecting it to Dar es Salaam and Nairobi. Most of the district is served by cell phones.

The district's HIV incidence has increased every year since 1998, with 3412 (0.65%) infected since 1988. Tuberculosis cases have increased rapidly because of the AIDS epidemic (NACP 2003). This affects agriculture by reducing the amount of available labour and increasing the time and resources needed to treat the sick.

The district has two farming seasons. There is little or no crop rotation, but intercropping is common. Maize is a staple food and largely intercropped with pigeon pea or *Dolichos lablab*. Livestock is a source of wealth, food and employment in the district. Most of the livestock are indigenous. Soil conservation includes constructed structures and plants to control erosion.

Different institutions have introduced and promoted conservation agriculture. The Selian Agricultural Institute (SARI) has been involved with conservation agriculture since 1999 and developed zero tillage, intercropping, and attaining and retaining soil cover. Heifer Project International, involved with dairy cattle, features soil and water conservation by having farmers establish fodder along constructed contours. Nandra Engineering Ltd is a private firm that produces conservation agriculture implements. The Soil Conservation and Agroforestry Programme in Arusha (SCAPA) has had a land management programme since 1989, including conservation tillage and improving water infiltration, all aimed at sustained improvement in crop and land productivity. Tanzania Engineering and Manufacturing Design Organization (TEMDO) and the Centre for Agricultural Mechanization and Rural Technology (CARMATEC) are public agricultural implement designers and manufacturers involved in producing

conservation agriculture implements. Research, Community and Organizational Development Associates (RECODA) started diversifying crops, reducing tillage and introducing cover and fodder crops. Tanganyika Farmers Association (TFA) is an agricultural supplier that sells conservation agriculture implements as well as other farm supplies. The Participatory Agricultural and Empowerment Project (PADEP) focused on alleviating farmer problems by using participatory approaches to improve livelihoods. Monsanto, a private firm, was involved in herbicides. Conservation Agriculture and Sustainable Agriculture and Rural Development (CASARD) facilitated and accelerated conservation agriculture by training farmers and supplying implements. Women's Agriculture Development and Environmental Conservation (WADEC) introduced conservation agriculture practices. The International Maize and Wheat Improvement Centre (CIMMYT) promoted conservation agriculture practices such as reduced tillage and intercropping.

In Arumeru farmers were interested in any technology that would increase yield at affordable production cost and save labour. The main conservation agriculture entry points include improving soil fertility, reducing soil erosion and degradation, reducing labour and increasing yields.

Conservation agriculture tests and implements technology that works. Suppliers of equipment for conservation agriculture mostly provide ripper attachments, subsoilers and direct ripper planters. They maintain and service the equipment. Conservation agriculture uses cover crops and crop residue as soil cover. Several cover crops were introduced to maintain soil moisture, reduce runoff, increase infiltration, reduce soil erosion, and increase and maintain organic matter through both dry and wet seasons. Generally, crop rotation is minimal and mainly practised in intercropped farms. Pigeon pea and maize are followed by pigeon pea alone, followed by maize and beans or lablab. Indigenous conservation agriculture knowledge existed before the current projects and its indigenous techniques were practised by farmers on their own. Agroforestry and contour construction are traditional and widely used, especially near Mt Meru. Other indigenous practices include intercropping pigeon pea, soybean, sweetpotato and pumpkin, which act as a cover crop after harvesting the main crop.

Although conservation agriculture is a recent concept in Arumeru District, the pathways to adapting and diffusing it have depended on agricultural development facilitators, the climate, the geography, the farming system and the socio-economics in which it was introduced. Small-scale farmers chose to use jab planters because they were easy to use and maintain. Conservation agriculture was associated with direct household benefits, involving farmer groups, availability of supplies, outsiders being motivated, and the weather.

The main approaches and methods used to adapt, disseminate and scale up conservation agriculture included farmer field schools, innovative farmers, farmer visits, group visits, tours, on-farm trials, demonstration plots, field days and extension publications. Adoption depended on finances, land tenure, age and amount of land owned.

The benefits associated with conservation agriculture influence households to use cover crops, train other farmers in 'exotic knowledge' and spread the technology.

It has shown increase in yields, reduction in labour, benefits on gender issues and improved livelihoods. It can ensure food and a harvest even in drought.

However, labour for weeding was not greatly reduced when only soil cover was used; those who used herbicides reduced weedings to two. Managing crop residue was a major challenge because most pastoralists grazed on harvested farms. Challenges and gaps included low adoption of conservation agriculture, inability to afford inputs, unfavourable land-tenure systems, inadequate supply of implements, lack of follow-up and coordination, inadequate skills in conservation agriculture, enforcement of unfavourable village bylaws, labour migration, inadequate soil cover, insufficient weeding, and the need to diversify crops.

Conservation agriculture is a promising technology but to make it sustainable, it must be adopted faster and more widely. It is vital to involve farmers in developing it to create their sense of ownership.

1 Introduction

The Tanzania Development Vision 2025 (URT 2000) provides guidance on national goals for social and economic development and highlights a change in approach and attitude to get there. Adopting and adapting conservation agriculture is a new approach to local problems. It involves opening up dense and compacted soils, restoring soils, opening minds and innovative thinking.

Arumeru District has experienced occasional drought and low crop yields from erratic and poorly distributed rainfall (Jonnson et al. 2003), poor soil cover and high rain runoff and evaporation. Few farmers use opportunities to better manage soil moisture, harvest rainwater and diversify crops to cope with drought. Relatively intensive farming results in degraded soils, depleted soil fauna, extensive soil erosion and soil moisture loss. Most rainfall never becomes available to crops; 15–25% of the rainfall never infiltrates but runs off the crusted soil. Evaporation accounts for half the loss, especially where mulching is not practised and the vegetation canopy is low. Similarly, poor water uptake by crops contributes to loss of rainwater (Jonnson et al. 2003).

Most rural households depend on crop and livestock production. Present yields have to double if demand for food by the rapidly growing population is to be met (Jonnson et al. 2003). Agriculture not only provides food for consumption, it provides income, shelter and energy for households. Small-scale farmers cultivate their land as often as possible to assure their subsistence. This leads to nutrient mining and loss of organic matter, since the land never rests. Overgrazing, deforestation and intensive agriculture combined with insufficient restoration of organic matter contribute to soil degradation in Arumeru District.

Conservation agriculture in Arumeru has taken place through the government, NGOs and the private sector. It embraces three main principles: crop rotation, soil cover and minimal soil disturbance. Soil cover protects the soil from the weather, regulates water infiltration, provides food for microfauna, and builds up organic matter (Steiner 2002a). Soil cover also protects the soil from raindrops, slows down surface runoff, and prevents seal formation (Nill et al. 1996).

This case study presents a history of conservation agriculture; it describes its technology, adaptation and adoption, experiences, challenges and issues in Arumeru District.

2 Methodology

The study used various participatory methods to collect information needed according to the case study framework. Sites were selected that had had a previous conservation agriculture project or current conservation agriculture activities or community organization or used any conservation agriculture principle. These sites included Kikatiti, Likamba, Manyire, Ngorbob and Sakila villages.

The case study team

The local team was formed, briefed and trained in the case study framework and how to guide the study. The team had personnel from Selian Agricultural Research Institute (SARI), Research, Community and Organizational Development Associates (RECODA) and the Arumeru Agricultural District Office. All members were well versed in conservation agriculture, especially as practised in Arumeru District.

Identifying conservation agriculture stakeholders and reviewing literature

Stakeholders were identified by their participation and teaching on agricultural equipment, crops, supplies, research, soil and water conservation. They included Tanganyika Farmers Association (TFA), Tanzania Farmers' Service Centre (TFSC), Nandra Engineering in Moshi, the Centre for Agricultural Mechanization and Rural Technology (CARMATEC), the Tanzania Engineering and Manufacturing Design Organization (TEMDO), Conservation Agriculture for Sustainable Agriculture and Rural Development (CASARD) and the District Agricultural and Livestock Development Office (DALDO). Others included Soil Conservation and Agroforestry Programme in Arusha (SCAPA), Help to Self-Help (HSH), Research, Community and Organizational Associates (RECODA), Selian Agricultural Research Institute (SARI), Monsanto, and the Kenya Network for Draught Animal Technology (KENDAT). Information from past and current projects, institutions, government reports, and other progress reports was used. (See appendix 1.)

Participatory rural appraisals

The case study team conducted key informant interviews with farmers who tried conservation agriculture and then abandoned it; farmers who practised conservation agriculture although not initially targeted for it; those practising and who were involved in projects; stakeholders and agricultural officers. Follow-up individual interviews clarified and enhanced the information gained in the first interviews.

Focus group discussions and workshops conducted were composed of village leaders, conservation agriculture farmers and farmer field schools. The field schools are formal farmer organizations centred on a theme. These schools used conservation agriculture to increase yields and conserve the environment.

Field visits

Field sites were chosen to see different conservation agriculture practices. The team visited fields, looked at the practices and took photographs. The sites included both individual and farmer field school farms. Information was collected from discussions and observations. The field visits clarified and confirmed information collected through other methods (table 1).

Table 1. Field visits

Site	Farm type	Conservation agriculture practice
Gomba estates	Large-scale vegetable farms	Tractor chiselling and subsoiling, crop rotation
Individual farms	Small-scale farms	Cover crop, reduced tillage with ripping, jab planter and direct planter
Demonstration trials	Small plots	Ripping, cover crop, farmer practice

Field visits and focus group discussions enhanced personal observations. Observable information included type of crops, extent of biomass and cover, farm equipment, livestock integration, terrain, drainage, vegetation and farm operation. The observations enhanced comprehension of responses given during focus groups and household interviews. The sites included both individual and farmer field school farms.

3 Context

Location

Arumeru is one of eight districts in Arusha Region in north-eastern Tanzania, between 35°E and 37°E and 3°S with 2966 km^2, 3.5% of Arusha Region. The district borders Monduli to the north and west, Hai to the east and Simanjiro to the south. It has six divisions: Enaboishu, Kingori, Mbuguni, Moshono, Mukulat and Poli, with 30 wards and 143 villages (Nyaki et al. 1991). The land is used as shown in table 2.

Table 2. Arumeru District land use

Land use	Area (ha)
Hilltops and gullies	102,840
Grazing land	58,765
Arable land	51,575
Water area	40,717
National parks	16,650
Not suitable	16,180
Forest	7,876

Source: Arumeru District office

Population

Arumeru District has 516,814 people (253,143 females and 263,671 males) and 113,002 households; life expectancy is 45–55 years (URT 2002a). Population density averages 110/km^2. The district annual growth rate is 3.1% (URT 1988). The Maasai people occupy the north, the Meru occupy the central part and a mixture of Chagga, Maasai, Mbulu and Meru occupy the south. Most people tend to concentrate on fertile soils in the Meru area. They have small landholdings on

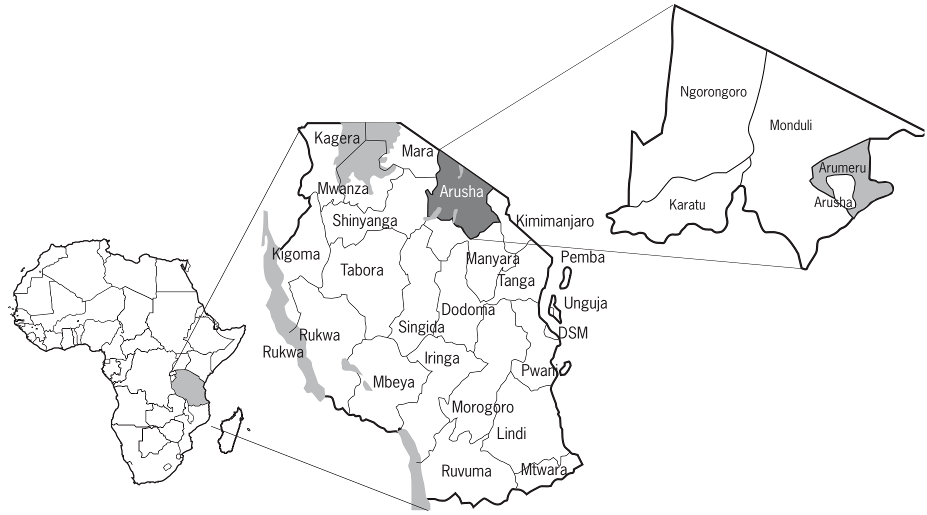

Figure 1. Arumeru District map (source: Arumeru District offices).

which they manage to produce just enough to subsist. In lower-potential areas, population pressure has led to deforestation in the search for more land to farm and rapid soil degradation, exacerbated by inadequate social services, such as education, health services and employment.

Geography

Arumeru District is divided into three major agroecological zones or belts.

The highlands

The highland area is densely populated with an average of 157 people/km^2. The annual rainfall is about 1000 mm or more. The area has the highest agricultural potential in the district with an altitude ranging from 1400 to 1800 m above sea level. Both traditional and modern agroforestry are practised. The major cash crops are coffee and pyrethrum. Food crops include banana, maize (mostly hybrids) associated with pigeon pea, beans, cowpea, vegetables and potato. Livestock includes cattle, goats and sheep, kept in a semi-intensive zero-grazing system. The main soil is volcanic, with some patches of red soil. The forest, managed as a water catchment, covers a large area.

The midlands

The medium altitude area, ranging from 1000 to 1350 m above sea level, is moderately populated, with 107 people/km^2 (Mwalley and Mawenya 2002). The midlands receive 700 mm or more annual rainfall. The major activities are crops and livestock. The area is dominated by annual crops with some coffee and banana. The maize varieties are mainly composites and planted with beans, pigeon pea and *Dolichos lablab*. Livestock keeping is semi-intensive (Jonnson et al. 2003).

The lowslands

The lowland belt is 800–1000 m above sea level, forming a moderately undulated landscape with clay loam soils. This area receives 400–700 mm annual rainfall, which is not well distributed. The area is sparsely populated. The population has fewer than 50 people/km^2 (Mwalley and Mawenya 2002). Rainfall distribution is unreliable and the soils are heavily compacted (Nyaki et al. 1991). Most rivers and canals from the upper zone distribute water to this zone, making most agriculture dependent on irrigation. Crop production is the major agricultural activity. Crops grown include horticultural crops, maize, beans, lablab and cassava. The livestock system is free range with large numbers of cattle, goats and sheep (Jonnson et al. 2003).

Rainfall

Rainfall in the last five years has been variable with heavy rains downpouring in a short period followed by a long dry spell, affecting crops. The short rains occur October to December, the long rains February to June. The evaporation rate is 150–200 mm annually. Temperatures range from 15 °C to 30 °C. (see appendix 2)

Drainage

Most upland rivers drain into the lowlands, influencing development and agriculture. All the rivers are on the windward side of Mt Meru, which receives the most rainfall. The district has six major perennial rivers: Burka, Kikuletwa, Nduruma, Ngaramtoni, Ngarenyuki and Temi. During the rainy seasons, all rivers are full, but in the dry seasons the water volume falls dramatically. Some rivers that used to be perennial have become seasonal.

Soils

Soils near rivers are alluvial. Areas below 760 m are dominated by shallow, highly fertile red soils with some areas having heavy black clay soils. Areas above 1000 m are dominated by medium fertile soils. The land is degraded with gullies and splash erosion.

Economic activities

According to Arumeru District records, farming and livestock are the main economic activities for most rural residents. More than 90% of the people are engaged in agriculture, producing both cash and food crops. Most farmers only practise rainfed cropping. Arumeru also hosts trade of goods between Kenya and Tanzania, tourism, and mining, mainly for tanzanite. The gross domestic product (GDP) for the district is TZS 2,787,500 with a per capita income of TZS 64,716 each year. (TZS 1000 = USD 1.)

The main on-farm income sources for smallholders include field crops, small animals and livestock. The main off-farm income sources are farm labour, implement repair, renting draught animals, groceries, trading, and salaries and wages.

Markets

The urban centres are Kikatiti, Kilimanjaro International Airport, Kisongo, Maji ya Chai, Ngaramtoni, Oldonyosambu, Tengeru and Usa River. Most of the food crops are sold at weekly open markets in urban centres within the district. Coffee, flowers and vegetables from large farms are marketed and sold through private buyers or cooperatives. The marketing system is heavily driven by informal networks and establishments. Tanganyika Farmers Association is a public organization. Input traders are agents, retailers and distributors dealing with seeds, fertilizers and chemicals. Market centres also have implement repair services, mainly for repairing animal-drawn implements.

Most often small-scale farmers sell their produce to traders and are expected to bargain for the price for their goods. According to farmers, crops like onion and tomato are sold cheaply because the farmers lack knowledge of how to store them and usually urgently need cash. This gives the trader an upper hand in bargaining. Seeds for cover crops, especially lablab, are mainly available from institutions practising conservation agriculture. After harvesting lablab, farmers get USD 100 for a 120-kg bag. Maize fetches TZS 18,000/100 kg at planting time, TZS 10,000–12,000/100 kg during harvest; lablab TZS 100,000/120 kg at planting time, TZS 40,000–50,000/120 kg during harvest (TZS 1000 = USD 1).

In Arumeru farmers lack an organized way to market their conservation agriculture produce. This means middlemen follow them to the farms and dictate low selling prices. The district is near the Arusha municipal centre, which is rapidly expanding and offers a ready market for most produce. There are also export opportunities through Kilimanjaro International Airport to Dar es Salaam and Nairobi for onion, banana and flowers (URT 2004). Agricultural stockists are also in the district or in Arusha city. Access to supplies by farmers in more remote areas is problematic, since stockists are mainly in urban and semi-urban areas.

Mechanization

About 60–70% of farming in Arusha Region is mechanized. According to the district agricultural and livestock development office, farmers use tractor-drawn disc and mouldboard ploughs, as well as animal-drawn implements. Between 30% and 40% of the arable land is cultivated with hand hoes. In 2004/05, out of the 51,575 ha of arable land 25,787 ha was ploughed by tractors, 23,209 ha by draught animals and 2,579 with hand hoes. In recent years conservation agriculture implements have been introduced, especially rippers, animal drawn no-till ploughs and jab planters.

Infrastructure

Good transport services, such as roads, connect Arusha to Dar es Salaam, Dodoma and Nairobi. However, most roads in the district are not paved and some areas are difficult to get to. Interior villages are adversely affected by inaccessible roads. The roads are poorly maintained and damaged during heavy rains but are relatively accessible during the dry seasons. Tractors, ox-carts, donkeys, pickup trucks, lorries, handcarts and wheelbarrows are commonly used by farmers during harvest. Most farmers hire tractors, pickups and lorries, since most cannot afford to buy them. Telecommunications in the area are good. A number of cell phone companies, Tigo, Vodacom, Zantel and Celtel, have networks in most areas. Some farmers have cell phones, making communication easier. There are also Internet services and two airlines fly frequently to Dar es Salaam, Nairobi and Mwanza.

Economic and cultural characteristics

The district is diverse in tribes and cultures. In the Maasai and Waarusha tradition, most households own goats and indigenous cattle. Medium-resource households own dairy cattle, while low-resource households own goats and sheep. Most villages graze animals freely in the village pastures and fields after harvest. During the cropping season high-resource households shift livestock to grazing land away from the villages and crops. Medium-resource households rarely shift their animals and mostly keep them indoors or tether them.

Hand hoeing is common, especially for small-scale farmers. The community regards a farmer as serious and competent when he or she uses a hand hoe to weed and keeps the farm clean; if old vegetative material lies on the soil the farmer is regarded as lazy. This is a constraint for changing behaviour to manage organic matter better. Preparing land is a man's job, while planting and weeding are mainly the women and children's responsibility, though men sometimes assist during weeding. Communities use traditional irrigation techniques. The district has a wide network of community organizations, NGOs and farmer groups.

Communities within the Arumeru District are receptive and entrepreneurial in their daily lives but have limited capital to finance agriculture. High supply prices and lack of agricultural credit facilities are compounded by no competitive financing or organized farmer groups, which reduce the credit-worthiness of farmers.

Health

Communicable diseases cause most illness and death in Tanzania. The leading five killer diseases for people five years and older are malaria (22%), clinical AIDS (17%), tuberculosis (9%), pneumonia (6.5%) and anaemia (5.5%). The district's HIV status has increased every year since 1998. Since 1988 the population infected is 3412 (0.65%). Tuberculosis has increased rapidly due to the AIDS epidemic (URT 2003). Arusha Region has a 14% HIV/AIDS prevalence rate (URT 2002b). Of the eight districts in Arusha, Arumeru District has the second highest number of cases, according to the phased-out World Vision Tanzania (2002) HIV/AIDS Project evaluation report. In Arumeru, there are probably more than 2000 cases and more than 240 orphans. Data in the district depend on voluntary testing. The number of affected people in various age groups is as follows: 5–14 years old (men 7%, women 13.8%), 15–34 (25% men, 52.4% women) and 35–59 (37.5% men, 47.2% women). This shows a wide gender and age bias in HIV and AIDS prevalence (Ringo and Manyelezi 2003). HIV and AIDS affect education and agriculture. The able age groups are vulnerable to the disease, reducing agricultural workforce. The pandemic has mainly hit the youth and middle-aged, who migrate to towns to seek employment in a limited labour market. Relatives of infected persons use resources and time to care for the victims instead of farming. The elderly in many cases are responsible for the orphans left behind by parents and labour-intensive agriculture is not suitable for them (URT 2002b).

Farming

Cropping calendar

The staple food crop is maize, often intercropped with beans or pigeon pea. The area has bimodal rainfall. In the short cropping season, called *vuli*, planting starts around October and November, and harvesting comes in late January and early February. The main and long season, called *masika*, follows immediately with land prepared by slashing and tilling soil with tractors, animal-drawn ploughs or hand hoes around December to January until the long rains start in March. Sowing follows in March through April with draught animals or hand hoes, with family or hired labour, if possible. Weeding, which requires intensive labour and engages the family almost full time, is done in May, mainly with hand hoes. It is done twice in the season. Maize harvest, normally in August, also engages the family intensely; pigeon pea is harvested in October. Beans are harvested in June. In some higher altitudes, with light, moisture-retaining, volcanic soils, dry planting is done in July, during the dry season after harvesting beans. Other crops are lablab, soybean, sweetpotato, mucuna, pumpkin and calabash.

Rotation

There is limited crop rotation, but intercropping is common among the small-scale farmers to maximize land with diverse crops. Farmers reported they have limited land to practise crop rotation. Land is too scarce for it to be left fallow or used for crops not used for subsistence or sale. However, with the recent introduction of lablab some farmers are planting a pure lablab stand, to be followed with maize in the next season. The main association is maize followed by pigeon pea or lablab. Therefore, land is used throughout the growing seasons.

Crop production

The main crops grown are maize, the staple food, intercropped with beans, soybean or pigeon pea. Farmers transport crop residue after harvest to the homesteads to feed animals. Crop residue is also lost through after-harvest grazing. Labour is both hired and from the family. Most farms rarely use fertilizer. Land is acquired through renting or inheritance.

There are several large farms of coffee, vegetables and flowers in the fertile piedmont of Mt Meru. Large-scale farming is highly mechanized and uses sophisticated drip irrigation, heavy machinery and well-organized marketing. These farms also employ many small-scale farmers with low agricultural productivity and youth. These farms provide extra household income.

Horticultural crops are grown, especially where irrigation is possible. Major horticultural crops include African eggplant, cabbage, cucumber, sweet pepper, banana, tomato, onion and French bean.

Crop and livestock interaction

Livestock is the main source of wealth, food and employment in many parts of the district. At present only 58,762 ha are devoted to livestock grazing, which is considered inadequate for the number of animals. Both zero-grazing and free-range systems are practised. Free-range grazing is confined to the steep slopes of Mt Meru and Sakila and to the less fertile and arid areas of Mukulat and Mbuguni Divisions. Most domestic livestock found in the district are indigenous, with cattle, goats and sheep making up to 60% of the total livestock production (Nyaki et al. 1991). Numbers according to district records are 432,462 indigenous cattle, 326,807 goats, 304,888 sheep, 136,250 donkeys, and 60,000 dairy cattle.

There is much crop and livestock interaction. Many poor farmers use draught animals. Donkeys are mainly used to transport fuel, wood, water and other farm products. Animals are a manure source to many households as well as a means of income from animal products. Heifer Project International has promoted dairy cattle. This has increased zero-grazing and diversified income through selling milk; free range is still largely preferred despite village bylaws. Farmers practising zero-grazing use crop residue to feed their animals and use the farmyard manure to fertilize their land. In Manyire and Likamba manure is required to plant banana suckers.

Soil conservation

Soil conservation includes both physical measures to control runoff and biological measures. Mechanical structures include *fanya juu*, a technique originating from Kenya. The soil is thrown on the upper side of the 50–60-cm drain channel that follows the contour. It can be either graded or done on a dead level contour, depending on the nature of the region (Elijah et al. 2000). Fodder crops are grown along the contour bunds to control soil erosion where water concentrates.

Contouring was promoted as early as the colonial period, when it was mandatory for farms to have contours. These practices have been promoted by government agencies through agricultural extension and development agents. Contours need constant maintenance. Many are already losing shape and capacity to prevent soil erosion, especially the ones developed during colonial times. However, areas with contour bunds are better off than those without contours in controlling soil erosion and reducing runoff. Making and maintaining contours is labour intensive and time consuming, leading to their unpopularity among the farmers.

Vetiver grass is planted on contours and its dense root network enables it to stop soil movement and trap silt. The large-scale farmers in Arumeru, particularly Gomba Estates Limited, use it. It has endured roaming animals and droughts, since vetiver is edible to animals only when young and is very drought resistant.

Fodder grasses such as elephant grass or Napier grass and tree legumes such as *Leucaena leucocephala, L. diversifolia, Calliandra calothyrus* and *Sesbania sesban* are planted along contours for fodder and controlling soil. Trees are traditionally grown by farmers, especially around Mt Meru. They provide shade, wind protection, fodder and fruit. They are planted along field boundaries, particularly around homesteads, roadsides and badly eroded areas. Live fencing is also used with species useful for animal feed and occasionally for mulching.

4 Conservation agriculture history

Institutions

See appendix 1 for a complete list of conservation agriculture institutes and projects.

Selian Agricultural Research Institute

The Selian Agricultural Research Institute (SARI) is the biggest agricultural research institute pioneering conservation agriculture. Its objective is to attain sustainable household and community food security. It focuses on crops, soils and livestock. SARI has several on-farm trials in Arumeru District, including integrated soil fertility management, zero-grazing and agroforestry. It conducts station trials, which many farmers visit during field days. Some of the demonstration plots include subsoiling, cover crops, intercropping pigeon pea, and crop rotation. The institute is also a resource centre for agricultural information.

SARI has been involved with conservation agriculture since 1999, developing no-tilling, intercropping, and soil cover. Similarly, SARI has been able to distribute cover crop seeds to the district council, farmers and conservation agriculture projects and is accelerating the use of cover crops. SARI collaborates strongly with other organizations. SARI has given lablab seeds to 586 farmers in Arumeru (see appendix 3.)

Heifer Project International

Heifer Project International has a long history in Arumeru District. It mainly promotes improved dairy cattle under zero-grazing. The project emphasizes establishing pasture before a farmer can receive a heifer and support from Heifer Project International. Pastures are established in plots and along contour bunds for fodder and stabilizing the bunds. Heifer Project has a strong influence on soil and water conservation, since a farmer has to establish fodder grown on contour bunds.

Soil Conservation and Agroforestry Programme in Arusha

The Soil Conservation and Agroforestry Programme in Arusha (SCAPA) is a community land-management programme, operating since 1989. In 1989, it observed that in various agroecological zones, crops and fodder had stunted growth, low productivity and sensitivity to even short dry spells. The roots of pigeon pea, shrubs and fodder crops revealed serious restriction from hardpan 10–12 cm below the surface (Mwalley and Mawenya 2002). The hardpan was caused by mechanized hoeing and ploughing.

SCAPA entered into partnership with RELMA and started introducing, testing and designing conservation tillage with farmers in 1998. Contour construction was undertaken by the new partnership. Later, it was apparent poor infiltration of rainwater into the soil led to high runoff between the *fanya chini* terraces (Mwalley and Mawenya 2002). Reduced tillage techniques, rippers and subsoilers, were introduced with complementary soil conservation measures and agroforestry. The aim was to have long-term improvement in crop yields and land productivity.

The programme has on-farm trial plots to test and develop, with farmers, conservation tillage under varying rainfall, soils, slope and use of farm machinery. In Arumeru District, farmers from three villages, Likamba, Ngorbob and Sakila, provide land for trials.

Research, Community and Organizational Development Associates

In 2003, Research, Community and Organizational Development Associates (RECODA), with Help to Self-Help in Tanzania and Danida, introduced diversified crops, reduced tilling, and cover crops in Likamba, Manyire, Nduruma and Ngorbob villages, with support from the Tanzania Assemblies of God. At the same time conservation agriculture was introduced to reduce soil erosion, conserve soil moisture and restore soil organic matter (RECODA 2005). The organization introduced fodder crops and is planting them along the contours— lablab, mucuna and improved pigeon pea—and breaking compacted soil with rippers. Banana leaf mulch, made from leaves and the pseudostem, are used for livestock feed, balancing the needs of both livestock and the soil. Three villages, with 300 farmers, benefited from lablab, pigeon pea and mucuna seed and rippers provided by the project. The organization works with other institutions and the government to enhance conservation agriculture.

Participatory Agricultural Development and Empowerment Project

The Participatory Agricultural Development and Empowerment Project (PADEP) is funded by the World Bank in collaboration with the Tanzanian government. Its focus is to ensure that farmers realize their problems and needs, use technology through participatory approaches, and design crop and livestock projects that will improve their livelihoods. In Arumeru District, the project targeted 30 villages by the end of 2005; 14 villages had already designed their projects. The farmers are organized in four groups in each village, each group with 40 family representatives.

Conservation Agriculture for Sustainable Agriculture and Rural Development in Southern and Eastern Africa

Conservation Agriculture and Sustainable Agriculture and Rural Development (CASARD) is a regional project in East Africa, with technical support by FAO, to facilitate and accelerate profitable conservation agriculture by small-scale farmers in Arumeru, Bukoba and Karatu Districts in Tanzania. It mainly uses farmer field schools, which emphasize farmer-created techniques. In Arumeru, six conservation agriculture facilitators helped 11 groups, 325 farmers (148 males and 177 females). Each group has a long-term lease on a trial plot.

The groups received basic training in conservation agriculture. Five farmers were trained to operate and maintain conservation agriculture implements. The groups meet weekly to work on agroecological analysis, an integral part of the farmer field school. Group leadership guides the groups through daily activities, discussions and decisions. The farmer group receives supplies and equipment from the project:

maize, pigeon pea, and lablab seeds, disease control chemicals, jab planters, no-till direct planters and Zamwipes, a herbicide applicator. The goal is to increase water infiltration, soil moisture, soil organic matter, and to reduce pests, diseases and soil inversion (CASARD 2004, 2005, 2006).

Women's Agriculture Development and Environmental Conservation

Women's Agriculture Development and Environmental Conservation (WADEC) provides support for community development and agriculture. It works with four groups, each with 10–15 members in Kulili, Malula, Mikuni and Ngumaneni villages. Farmer-managed demonstration plots have been established. Farmers are trained in good crop husbandry using improved varieties and organic farming. The organization recently introduced pigeon pea as a cover crop.

International Maize and Wheat Improvement Centre

The conservation agriculture maize project of CIMMYT, the International Maize and Wheat Improvement Centre, was started in Mareu village in Arumeru. The project started in Mareu as a pilot; five farmers were selected after a village meeting in October 2004. The farmers did 1) ripping and maize intercropped with lablab, 2) no ripping and maize intercropped with lablab, and 3) intercropping maize with beans and sunflower or either of the two. The second season, 2005/06, the first two treatments had vigorous maize. Labour was reduced from four people to two per acre at seeding time and reduced from eight to two hours with a direct animal planter. During June 2006, the five farmers formed groups of 8–13 farmers; 64 farmers now practise conservation agriculture by growing *Dolichos lablab* in their maize plots. They have requested rippers and direct planters for 2007 (CIMMYT 2005)

At farmers' request a research trial on controlling insect pests in lablab was started in 2006 at SARI and Mareu. The initial data and field observations from SARI in July 2006 showed pod production was higher where lablab was treated with neem oil or Karate insecticide. Lablab recovers its canopy quickly and insect pests do not affect the biomass required for soil cover.

Nandra Engineering

Nandra Engineering Ltd is a private agricultural implement designer and manufacturer. Nandra manufactures animal-drawn rippers and spare parts for rippers and tractors on request. Nandra was selected to produce and distribute implements through the Tanganyika Farmers Association. The company makes animal-drawn rippers, ripper planters, chisel ploughs, weeders and cultivators and ox carts (Bishop-Sambrook et al. 2004).

Tanzania Engineering and Manufacturing Design Organization and Centre for Agricultural Mechanization and Rural Technology

The Tanzania Engineering and Manufacturing Design Organization (TEMDO) and the Centre for Agricultural Mechanization and Rural Technology (CARMATEC) are public agricultural implement designers and manufacturers. Providing the agricultural sector with skilled engineers and machines, they can design and manufacture many agricultural implements. TEMDO is an applied engineering research and development institute that designs and manufactures manual and engine-driven postharvest equipment. It produced 10 rippers and subsoilers for the Soil Conservation and Agroforestry Programme in Arusha. CARMATEC in Arusha deals in animal-drawn rippers and mouldboard ploughs. It made more than 150 jab planters (Bishop-Sambrook 2004).

Tanzania Farmers Service Centre

Incorporated in the 1990s, Tanzania Farmers Service Centre Ltd (TFSC) is a private company that provides small- and medium-scale farmers with agricultural services. It sells agricultural machinery, provides workshops on equipment repair and hires out machinery. The organization also holds workshops and courses on sustainable agriculture, using agricultural machinery and efficient crop production. It provides machinery for demonstration trials, seeds and expert support for conservation agriculture. In 1999, the centre started on-farm trials with conservation agriculture, mainly in cover crops combined with direct planting, using hand and animal-drawn seeders. It contracted with SARI to conduct the on-farm field days and training workshops, which were technically and financially supported by the German Development Bank and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit). In Arusha in 2003, the centre organized the first national workshop on conservation agriculture (interview with TFSC manager). CASARD uses the experience gained in Arumeru. The Arumeru D

istrict centre hires out subsoiling and direct planting equipment to commercial farmers.

Tanganyika Farmers Association

The Tanganyika Farmer Association (TFA) is the only agricultural supplier with ordinary farmers as members. For a membership fee of TZS 15,000 (USD 15) farmers receive a discount on purchases, access to credit, a share in dividends and get free advice (Bishop-Sambrook et al. 2004). It has branches in several regions and districts. They conduct small-scale farmer days every August 8, *nane nane*, and ensure farmers get quality supplies at reasonable prices. Because of its reputation with small-scale farmers, Nandra used the farmers association to distribute its conservation agriculture implements, such as rippers, chisel ploughs and ripper planters. However, neither the Tanganyika Farmers Association nor Nandra have systems to introduce technology to farmers or get feedback on them.

Monsanto

The private company Monsanto has been marketing Round-Up herbicide in the district through demonstrations in farmers' fields comparing zero-tillage with conventional practice. According to Emmanuel, a farmer in Kikatiti, Monsanto carried out the trials with minimal farmer involvement; the harvest was given to the participating farmer as reward for offering the land for trials. Most farmers who had Monsanto trials increased yield during the trials but later the Atrazine herbicide was completely abandoned due to its residue effects in the soil and the lack of money to buy it. During the trials, farmers mixed Round-Up with Atrazine, which reduced growth on legume crops. Farmers in Kikatiti normally intercrop maize with beans or pigeon pea. Monsanto, after failing to convince farmers to use their herbicides, moved out of the area.

5 Conservation agriculture practices

Introducing conservation agriculture

Conservation agriculture is based on three major principles:

1. Minimal soil disturbance with reduced tillage, zero tillage and direct planting
2. Permanent soil cover, with the crop itself, cover crops, residues and mulch, to protect the soil from sun, rain, and wind and to feed soil organisms
3. Crop rotations through crop sequences, intercropping, relay cropping or mixed crops to avoid diseases and pests

Labour shortage and low yields

Farmers are interested in any technology that will increase yield at an affordable cost and save labour. The elderly complained of drudgery, especially during weeding in conventional practice. Manual weeding is labour intensive. By the time a farmer is through with weeding the entire farm, the part weeded first will usually show signs of new weeds and weeding has to be repeated. Therefore, families will weed only where they can and the remaining part will be done if they can afford hired labour. Similarly, preparing land is very labour intensive, engaging whole families and renting draught animals for those who do not own cattle. This leads to low yields from poor timing, late planting and inefficient rainwater use.

Soil fertility and degradation

Steiner (2002a,b) reported that soil organic matter decomposes more rapidly in the tropics because of the higher temperatures; soil inversion increases soil aeration and accelerates decomposition. During the focus group discussions, farmers concurred with Steiner: the main aim of soil inversion is to bury crop residue, thus producing optimal conditions to germinate seeds, increase water infiltration and eliminate weeds. However, with time, such practices exhaust soil organic matter. Steiner also noted that losing soil organic matter deteriorates soil structure, crusts and seals the soil surface. SCAPA and RELMA identified soil hardpan, soil nutrient depletion, and low soil moisture content as a result of poor retention and failure of rainwater to infiltrate as the main yield constraints (RELMA 2002). As a result cover crops were introduced, mainly through SARI, to provide soil cover to replace the crop residue already depleted from grazing.

Soil erosion

Soil erosion is more pronounced in the maize and beans system in the lowlands. It is still a major issue in the district despite the conservation programme's significant efforts in facilitating the construction of terraces and contours, and agroforestry. Unfortunately, contours and agroforestry did not result in a significant increase in yields, but they did reduce runoff and increase infiltration. Contour construction was perceived as tiring and separate from routine land preparation. Few farmers adopted contours and many recently constructed ones were either destroyed or poorly maintained (RELMA 2002). Contour bunds did not enhance water retention, but with the Heifer Project, where fodder was planted alongside the contour bunds, runoff was minimal. Further investigations on pigeon pea, shrub and fodder crop roots revealed serious restriction in root depth and water infiltration from hardpan (Mwalley and Mawenya 2002).

From the early 1980s Arumeru District has had occasional drought from erratic rainfall, poor rain distribution, lack of good rainwater management and inadequate crop diversification (Mwalley and Mawenya 2002). In the past much effort was made to conserve soil and water with terraces and contour bunds. This has proved inadequate. Water conservation depends a lot on how the soil is tilled and its effects on soil structure, compaction and soil organic matter. Exposing the soil to sun and rain leads to crusting, runoff, soil erosion and degradation. Therefore, conservation agriculture can address the low yields under small-scale farming by tackling low soil fertility from depleted nutrients, poor soil moisture-holding capacity, hardpan, soil and water erosion, organic matter loss, labour shortage, and inadequate and uneven rainfall.

Implements and power

The main implement suppliers and implement services are TFSC, Nandra Engineering and TFA Arusha. They mostly provide ripper attachments, subsoilers and direct-ripper planters. They also maintain and repair the implements. The services are limited, since the suppliers are mainly in urban centres. Conservation agriculture implements include the jab planter, hand hoes, pangas, slashers and animal-drawn implements, including the ripper, direct seeder, no-till ripper and Zamwipe, although it is not widely accepted or used yet. Cost of these implements is indicated in table 3. Draught animals are the main source of power; they may be owned, shared or hired and are mainly used by small-scale farmers.

Table 3. Cost of conservation agriculture implements

Implement	Cost (TZS)
No-till ripper planter	250,000
Ripper with attachments	175,000
Jab planter	45,000
Zamwipe	20,000
Hand hoe	5,000
Panga	2,500
Slasher	2,000

TZS 1000 = USD 1

Most of the implements, except the hand hoes, pangas and slashers, have been introduced through conservation agriculture organizations. Small-scale farmers prefer less costly and uncomplicated equipment, such as jab planters, hand hoes and animal-drawn rippers. Most conservation agriculture equipment was provided by projects. This has led to sharing equipment, especially the animal-drawn ripper and the direct seeder. If one is not available, farmers use hand implements to turn the soil. Artisans who have been trained by the rural development project to maintain implements assist in making them. The first locally produced rippers could not reach the required depth. Local artisans adjusted them.

Subsoilers were introduced to both small- and large-scale farmers. The soil conservation programme demonstrated the Palabana subsoiler, widely used in Zambia. The farmer service centre hired out their subsoilers at TZS 13,000 per hour, according to their 2003 price list, a cost most small-scale farmers could not afford, limiting their use. Large-scale farmers preferred to use subsoilers and benefit from the saving in fuel and labour. Animal-drawn subsoilers have just been introduced in the district by the CASARD project, so little information is available.

Ripping has been promoted and is done before the onset of rains to harvest rainwater. It is mainly done with a draught animal and is 30 cm deep, leaving ripped lines to sow seeds with hand hoes and jab planters. This allows for proper timing with the rains.

Minimum tillage aims to reduce soil erosion by using hand hoes, ripping, herbicides, direct planters and, for large-scale farmers, chisel ploughing. Zamwipes have not been widely adopted and institutions, especially SARI, are still demonstrating them. Ripping has been promoted by institutions since 1998 in Arumeru District, but adoption has been slow. This can be attributed to uncoordinated efforts by stakeholders, lack of available equipment, especially after projects are phased out, and few trained artisans.

Soil cover

Various cover crops have been introduced to maintain soil moisture, reduce runoff, increase infiltration, reduce erosion, and increase or maintain organic matter throughout the year. Some farmers growing bananas have adopted grass strips and only dig holes to plant the suckers and mulch with crop residue.

In Arumeru District the cover crop choice usually depends on whether the crop can be eaten as much as on its capacity to improve soil fertility, conserve soil moisture and increase soil organic matter. Because lablab, pigeon pea and pumpkin are edible they are secure in their inclusion as cover crops in Arumeru District.

Good cover crops suppress weeds. In Manyire, intercropping is done after two weeks and total cover is attained after four weeks. Permanent soil cover is still a challenge. During drought the cover crop competes for moisture with the main crop. Livestock competes for the crop residue with free grazing. The maize stover is used as fuel. Pests invade lablab. Conservation agriculture farmers struggle with these challenges to maintain soil cover. Yet they do cover their soil, mainly from crop residue and from weeds uprooted and left to dry and die on the field rather than being carried home for animal feed. However, this does not provide much soil cover because of free grazing.

Cover crops, particularly mucuna, lablab and pigeon pea, are managed by slashing them after harvest then leaving them to sprout and provide soil cover for another crop, usually maize. In some cases, the cover crop is left to wilt after harvesting the beans.

Crop rotation

Most small-scale farmers have not achieved formal crop rotation. The main reasons are shortage of land and the traditional practice that a farm can never be left fallow for a season without planting maize, the staple food in most areas. The area under maize cannot be reduced. The only rotating is to intercrop other crops with maize. This maximizes the use of the field, which may yield more than one crop.

Conservation agriculture intercropping and crop relaying are mainly with maize and legumes. Maize is intercropped with lablab, pigeon pea, soybean and beans. Crop rotation is minimal and is mainly practised in intercropped farms with pigeon pea and maize, followed by pigeon pea alone, followed by maize and beans or lablab. Vegetable farmers often plant maize and beans, then vegetables, then maize and beans. Rotating crops can restore soil fertility and increase soil organic matter, depending on the crops used.

Indigenous knowledge

Indigenous knowledge has been practised by farmers before conservation agriculture projects. In coffee plantations, farmers practise no-till technology with minimal soil inversion during the initial planting. Weeding is done by scraping the soil. The leaves that fall and are pruned are spread on the soil. Since coffee is a perennial crop, this is beneficial to the soil. Minimal herbicide is applied.

Agroforestry and contour construction is traditionally widely used, especially near Mt Meru. They have been practised since colonial times and integrate well with conservation agriculture in conserving water and soil. Trees are mainly grown to provide shade, prevent wind erosion, provide fruit and fodder and mark territory. The unique coffee, banana, maize, beans and tree agroforestry system has survived for the past 200 years. Coffee and banana are planted under trees grown for timber, fruits, medicine, animal fodder and shade. The system provides continuous ground cover and a high nutrient cycling (Kaihura et al. 2001).

Other indigenous practices include intercropping pigeon pea, soybean, sweetpotato and pumpkin, which act as cover crops after the main crop is harvested. They provide a good canopy if densely planted. But pumpkin usually covers only small parts of a field during its growing stage. Pigeon pea provides biological chiselling. Its tough tap root breaks hardpan and may be cheaper and more sustainable, though slower, than ripping or subsoiling, since the root channels remain in the soil (FAO 2002). Pigeon pea may help to prevent compaction of subsoiled plots.

6 Adapting and diffusing conservation agriculture

Pathways

Conservation agriculture is a relatively new concept in Arumeru District. The pathways to adapting and diffusing it have depended on agricultural development facilitators, the farming systems, economics and culture. Moreover, within a village, pathways depend on household innovativeness, purchasing power and the ability to associate with other farmers to learn. A farmer's economic and social status affects adopting an innovation.

Small-scale farmers choose jab planters because they are easy to use and maintain for farmers who usually use hand hoes. For a farmer with more than one acre, a jab planter is not useful. These farmers choose animal-drawn implements, like rippers and direct seeders, because they reduce drudgery, labour and save time. They like direct seeders because they can plant straight rows and maximize seed use, so there is no need to thin later on. In conventional planting, two to four seeds are put in a hole, necessitating thinning later on.

Large-scale farmers use their own tractor-driven machinery, including subsoilers, or hire them from the Tanzania Farm Service Centre. Commercial farmers have adopted conservation agriculture over the decade, abandoning disc ploughing in favour of tractor-driven chisel ploughs, to harvest water and save on diesel (Mwalley and Rockstrom 2002). Farming pigeon pea intercropped with maize has been a traditional, continuous practice among farmers in Arumeru. This made it easier to have pigeon pea as a cover crop, rather than velvet bean (mucuna) and lablab.

Conservation agriculture is associated with other direct benefits to the household, especially the cover crops. Mucuna bean is not associated with economic gain, leading to its slow adoption. But by diversifying crops farmers have realized that mucuna offers good soil cover, especially when intercropped with banana. Lablab offers good soil cover and biomass and is preferred over mucuna, since it is edible. Among the Meru people it is a delicacy, prominent during cultural initiation ceremonies and suitable for feeding lactating mothers. Lablab and pigeon pea are readily sold in local markets. Lablab in Arusha can fetch as much as TZS 120,000/120 kg (USD 120 compared with USD 18 for maize). In Sakila, pigeon pea is mainly grown for sale; it is uncommon to use it as food.

Another important pathway is through involving farmers in farmer groups. It is evident, even during the discussions, that farmers who were members of farmer field schools were more knowledgeable on conservation agriculture and were ready to experiment with conservation agriculture on their own farms. In Manyire village, a CASARD site, Mrs Temu, Pastor Humphrey, Hilda Chondo, all farmer field school members, managed to set aside land to try conservation agriculture. Different farmers adopted different practices. Mrs Temu was given a plot by her husband. She practised no-till by using herbicides and ripping when she planted maize intercropped with lablab on one side of the plot and maize and pigeon pea on the other. Pastor Humphrey started by constructing contours and planting fodder crops along the contours. He ripped his farm and did shallow uprooting of weeds. He also planted maize, lablab and pigeon pea. Mama Hilda Chondo rented a piece of land and, despite being uncertain if she would have the land the next season, she ripped and planted maize with lablab and maize with pigeon pea. She also irrigated during the dry season.

Some farmers use conservation agriculture on and off, depending on supplies, motivation from outsiders and the weather. Pastor Mbise from Sakila adhered to conservation agriculture during the Soil Conservation and Agroforestry project. His farm had nicely done contours and he still has a ripper. However, after the project was phased out he despaired and reverted to conventional tillage, citing lack of financial power to purchase certified seeds and herbicides.

In Ngorbob village, weather dictated the amount of soil cover. Drought led to poor biomass and soil cover. Lablab was greatly affected, just like other crops, by the drought in 2002/03, making it impossible to benefit both the farmer and the soil. This led to some pioneer farmers abandoning soil cover and embracing ripping. Those who ripped their farms were able to sustain some crops.

Experienced and innovative individuals, like Thomas Loronyo, who have been keen to put into practice what they have been taught, have a well-defined farm layout with contours and agroforestry. Such farmers embrace technology from different sources to improve their food security and pass on knowledge to other farmers. According to Loronyo, while he has managed to adopt land ripping and crop rotation, he failed completely to adopt permanent soil cover because of drought, termites and free-range grazing. However, he is happy with ripping, since maize yields increased threefold and have been able to withstand at least some drought.

Among livestock keepers, maize stover is still being removed from the field for feed, while pigeon pea, mucuna, and lablab are left to provide cover. The introduction of elephant grass has reduced dependence on crop residue and cover crops for animal feed.

Approaches and methods

The main approaches and methods used to adapt, disseminate and scale up conservation agriculture include forming groups, especially farmer field schools, using innovative farmers, farmer visits, group visits, study tours, on-farm trials, demonstration plots, field days and extension publications.

Most conservation agriculture organizations train individual farmers on certain conservation agriculture techniques as the main approach. RELMA in partnership with SCAPA mostly trained innovative farmers on agroforestry, contour development, and crop and livestock management. They wanted to develop farmer trainers who would later train other farmers. Diffusion was slow, since the farmer trainers were few and had social obligations. The farmer trainers were also not paid to teach their fellow farmers.

Another common approach was the demonstration trial. SCAPA held demonstration trials to test and develop different systems of conservation tillage in partnership with farmers with varying rainfall, soil and farm machinery. This was done in three villages with eight farmers (Mwalley and Mawenya 2002). CIMMYT also held trials in Mareu village. They started with five farmers and three treatments: ripping with lablab intercropped with maize, maize intercropped with lablab with no ripping, and conventional practice (CIMMYT 2005).

In 2004, Conservation Agriculture and Sustainable Agriculture and Rural Development introduced the farmer field schools. This is an ongoing project. According to farmers, the approach is much preferred to the innovative farmer one. Field school farmers can share experiences easily, motivate one another to carry on and are encouraged to teach others. The field schools have shown signs of widely diffusing conservation agriculture. They own and manage acre plots, with five trial plots of the following treatments:

- Plot 1: maize + lablab, no ripping
- Plot 2: maize + lablab, ripping
- Plot 3: maize + pigeon pea; no ripping
- Plot 4: maize + pigeon pea, ripping
- Plot 5: traditional practice

Diffusion has also taken place through group visits—from one village to another and one person to another. The Participatory Agricultural Development and Empowerment Project is currently supporting field school groups for other projects—for dairy cattle, cattle and farmer visits. King'ori village visited Merikinoi Field School farmers to experience conservation agriculture. The empowerment project is also providing a 75% subsidy for conservation agriculture implements for the newly formed farmer field school in Arumeru District (CASARD 2005)

SARI has offered research and training to enhance conservation agriculture technology. It distributed seeds to farmer groups and other organizations; 586 farmers received lablab seeds. SARI distributed seeds to seven World Vision farmer field schools with 15 farmers each, 324 farmers, new field schools with 28 farmers, 8 farmers in Likamba village, 24 farmers with Women's Agriculture Development and Environmental Conservation (WADEC), 14 Roman Catholic Women Arusha farmers, 50 farmer with ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), and workers at SARI. Women's Agriculture Development and Environmental Conservation is an NGO that started two groups on conservation agriculture in Mareu, Malula, and Kolila villages, with technical support from SARI. They used the CASARD village facilitators to train their groups.

RECODA started with two groups under sustainable agriculture in Manyire. In 2006, RECODA distributed cover crop seed: 300 kg lablab, 300 kg pigeon pea and 100 kg mucuna to more than 100 farmers in Manyire village. The organization has spread the technology to 10 more villages and has 22 new groups using conservation agriculture.

Government extension staff provide technical support, supervise, monitor, collect and compile data in most of the projects. Soil samples are taken, depending on the project demands, and sent to a soils laboratory at SARI to analyse nutrient and organic content and soil moisture.

Diffusing conservation agriculture was enhanced by demonstrations, whether in farmer groups or by individuals since it was easy for farmers to see the results on farms. Farmer participation in new technology supported diffusion.

Arumeru has 10 farmer field school groups. The field schools in Manyire village, Matonyok and Vukani have about 60 farmers, each having tried one or two conservation agriculture techniques on their farms. Fifty-three have ripped their farms and all have planted lablab and pigeon pea. These techniques have spilled over to the entire village and nearby Nduruma village, where rippers and cover crops are greatly appreciated and needed. In Likamba, of the 22 Eutulelo Farmer Field School members, 18 ripped their own farms and all were able to plant lablab as a cover crop. Since a farmer field school involves many farmers—a group has 25–30 members—what is learned is easily talked about, challenged and implemented in the village, giving conservation agriculture a chance to prove whether it can improve yields and farmer livelihoods. In each group 10 farmers volunteered to practise conservation agriculture on their farms and regularly monitor progress until harvest. These farmers were able to see the improvement in their fields under conservation agriculture over those with conventional tillage.

Incentives

External pressure has been put to bear that incentives be provided to farmers participating in testing any new technology. Thus there are now local expectations of incentives for whoever participates in any development effort. Some farmers proved unwilling to participate without such rewards, and their attitude discouraged their groups.

During conservation agriculture adoption, the projects provided supplies such as seeds, inorganic fertilizers, herbicides, rippers, jab planters, direct seeders, Zamwipes, contour equipment, training, paper during training sessions and field visits. Farmers provided land, labour, active participation and security of the crop. In the CASARD project farmers were expected to keep records of their group performance and monitor the crops at both their farms and their group trial plots.

Incentives, or even the promise of incentives, is a sensitive issue regarding the continuity of conservation agriculture. If incentives were withdrawn, especially the equipment, farmers tended to go back to old practices, even though conservation agriculture was viable. This happened in Sakila. According to Pastor Mbise, the early withdrawal of the project greatly affected farmers, since they had only one year's SCAPA experience, which was not enough. Although they were left with the rippers, they did not continue conservation agriculture because they expected more incentives.

Policies and bylaws

In most villages, bylaws limit free grazing on cropland when crops are growing. The bylaws are supposed to be reinforced through fines, but their enforcement by community leaders is weak. The tradition is to let animals graze after harvest. During the dry season pasture is scarce, so grazing sometimes extends to cropland. In 2003, although the season was very dry, Thomas Loronyo's farm had a good canopy of lablab. But neighbours grazed his farm at night and left his land bare. Being a conservation agriculture pioneer in Likamba, since 2002 he has pushed for recognition and enforcement of the bylaws controlling grazing, but with minimal success. However, in 2006 the village government set priorities on environmental issues and reduced free grazing. The animals have been moved to other areas with adequate grazing land.

Currently the government is keen on conservation agriculture and has made it a major concern. The agricultural policy of Tanzania discussed alleviating poverty and reducing hunger by 2025, using available resources in farming communities. In 2006, the department of the Ministry of Agriculture that handles mechanization gave a boost to disseminating conservation agriculture by supporting farmer field schools in 10 more districts and 10 oxen training centres. The ministry is supporting farm supplies such as cover crop seed, fertilizer and rippers. The government opened a credit line for farmer groups to buy conservation agriculture implements and trained village facilitators to promote conservation agriculture in the rest of the country. The government currently supports local laws prohibiting grazing on farms after harvest, which was limiting conservation agriculture adoption.

7 Conservation agriculture effects

Agronomics and environment

Yield

Although conservation agriculture in the district is still at an early stage, farmers often see yield increase in the second year. During the 2004 drought in Likamba, even though adequate cover was not attained, farmers who had ripped their land and planted lablab with maize were able to harvest at least 5–8 bags of maize per acre, while conventional farmers harvested nothing or less than a bag per acre. They showed conservation agriculture was able to ensure an adequate harvest even in drought.

Makundi's success story

Pastor Humphrey Makundi has one acre in his nearby farm. Normally he would harvest 6 bags of maize. He ripped with improved maize seeds intercropped with lablab. He also established contours that reduced runoff on his cattle pasture. He managed to harvest 10 bags that season [2004]. In the following season he rented four more acres and harvested 10 bags of maize from each acre, totalling 50 bags in one season.

The significant increase in maize yield, 60–70%, might have been from conservation agriculture and improved seeds. Ripping is done before the onset of rains. In most cases, conventional farmers changing to conservation agriculture start with ripping their land, which is associated with increased yield. On the farmer field school trial plots water infiltration was visible. Reduced runoff was more evident in a ripped plot with a lablab cover crop, even during irrigation. Crop vigour was good compared with that on conventional farms. An Arumeru Farmer Field School member said, 'Using a no-till direct planter saves on seed [one seed per hole], reduces waste, and produces a straight row with accurate seed spacing.' The ripper is also thought to increase yield due to proper spacing and improved seeds.

Labour

Most farmers depend on family labour but hire additional labour during labour peaks, like weeding. Therefore, reducing labour is crucial to farmers. Labour to prepare land, slash, collect trash, burn and till can be reduced to slashing only (table 3).

Conservation agriculture definitely affects labour. For example, with conventional farming, at least three people are needed per acre to till the soil and plant with the animal-drawn disc plough. Generally, men guide the animals and ploughs and women and children follow, planting and covering the seed with their feet. With the introduction of direct seed planters, fewer people are needed to plant. At most, two people are required to rip, plant and cover the seed on two acres in one day. Direct seeding reduces drudgery and frees up time for people to rest and attend to other chores. It saves energy used for thinning. Conservation agriculture has also reduced time for tilling the field by half. Land preparation was reduced. In conventional farming, a farmer must slash, burn and plough before sowing seeds. Conservation agriculture offers a choice. Herbicide needs two people for one day to spray more than an acre. Slashing previous crops or any vegetation may take about three to four people about two days. Labour for weeding was not greatly reduced, especially since conservation agriculture is still at an early stage in the district. Other ways of dealing with weeds were more time consuming, especially uprooting. In conservation agriculture preparing land by ripping can be done by men or women, while in conventional farming men mostly do the ploughing, which is regarded as heavy work. See figures 2 and 3.

On most conservation agriculture farms, men work more than with conventional agriculture. The amount of hired labour has also increased because more land can be cultivated.

Managing weeds

According to Mwalley and Mawenya (2002) during the SCAPA trials, rampant weeds competed with the crop, leading to two or three weedings. During the second and third seasons the weedings reduced to two. Farmers are gradually changing from turning the soil during weeding to scraping and uprooting them. Most farmers agreed that during the first season uprooting weeds was cumbersome and very tiring, since the farmer must bend for a long time, leading to backache.

> Pastor Nelson started using a lablab cover crop on his banana farm in 2003. In conventional farming he used three days to weed his farm. He no longer weeds. Instead he harvests the beans and leaves the lablab to wither. The next season he uses herbicide on the emerging weeds and again plants lablab with a hand hoe.

Table 3. Labour for conservation agriculture and conventional farming

Activity	Conservation agriculture			Conventional agriculture		
	Labour/acre	Implements	Time	Labour/acre	Implements	Time
Preparing land	2–3 people slash and rip land	rippers, slashers, pangas	2 days slashing; 1 day ripping	slashing and burning, ploughing, 2–4 people	slashers, pangas DAP disc plough	4–5 days 3–4 days
Planting	2 people	direct planter	1 day	3 people	DAP	3–4 days
	2 (apply fertilizer and seed at same time)	jab planter	2 days	4 people (2 to make holes, 2 to plant seeds)	hand hoe	6 hr
Weeding	8–10 people done once	uprooting, scraping	1 day	8–10 people done twice	hand hoe	1 day
Spraying herbicide	2 per acre		1 day			

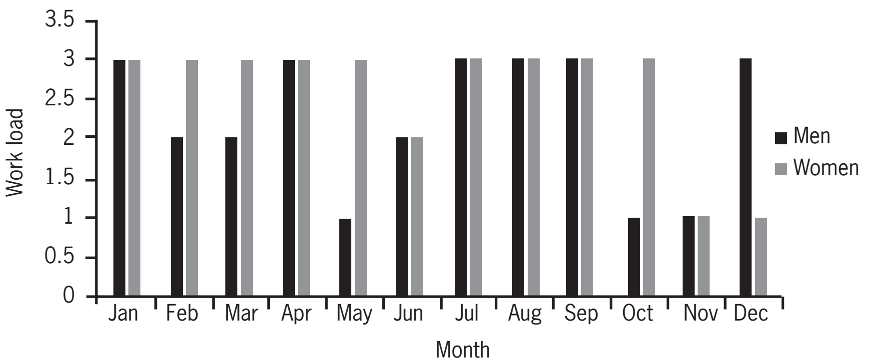

Figure 2. Labour situation 10 years ago.

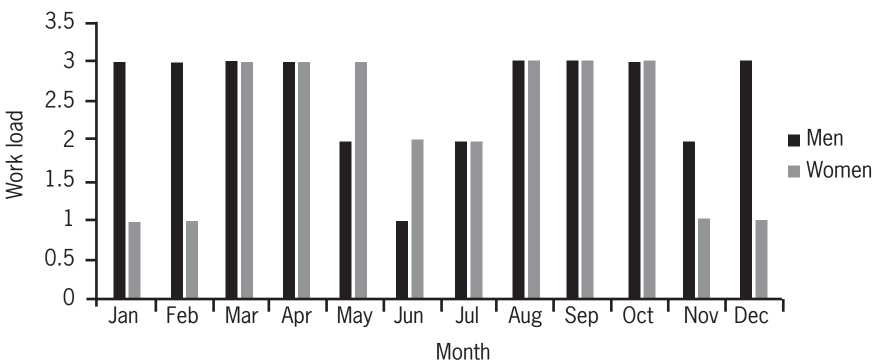

Figure 3. Current labour situation.

As farmers gradually convert from conventional to conservation agriculture herbicides are seen as a good investment. They reduce labour during weeding and preparing land. However, only a few can afford them (table 4).

Table 4. Labour and cost in conservation and conventional agriculture

Activity	Conservation agriculture		Conventional agriculture	
	Labour	Cost (USD)	Labour	Cost (USD)
Preparing land	herbicide spraying once	8	slashing, burning, ploughing	30
Weeding	renting sprayer, spraying and ripping	3	weeding 3 times x USD 8	24
	using herbicide	8		

USD 1 = TZS 1000

Those who use herbicides save on cost and time. Yet most farmers said they would still use family labour, although they would prefer using herbicide. Family labour is cheaper, but it takes more time and greatly tires the family. Farmers who could afford herbicide used less labour for preparing land and weeding. Farmers who relied on cover crops alone to manage weeds did not attain much benefit, because of free grazing.

Mama Mchome, an elderly lady and farmer field school member, depends totally on family labour and cannot afford to hire casual labourers. Due to her limited income, she could not buy herbicide. Though she had conservation agriculture knowledge, weeding remained a problem. The family therefore ripped the farm to increase water infiltration, but during weeding they inverted the soil because the weeds were overwhelming and uprooting them was time consuming. Other farmers have practised uprooting weeds.

Planting calendar

Under conservation agriculture farmers changed the timing of their farm operations. While the conventional farmer ploughs, slashes or burns residue, conservation agriculture farmers rip their farms to absorb the rain and plant on time, which provides good seed germination. Rippers were mostly acquired from conservation agriculture projects and were shared. Ripping, which needs proper timing, is done along planting lines. The interrows are left undisturbed during planting. Farmers realized that jab planters and no-till direct seeders were effective before the rains started. Planting is still done during February or March, depending on the onset of the rains, but the labour is well distributed, since the cover crops are harvested after the main crop. This gives more opportunity to hire out to harvest cover crops during off seasons.

Irrigation

In Arumeru, irrigation is the key to agricultural success. Farmers who have access to irrigation water are seen as better off than those depending on rainwater. Farmer field school plots in Manyire and Mlangarini were irrigated. The water on irrigated, ripped farms slowed down and mostly followed the ripping lines.

Timeliness in irrigating a farm is also important. There was a positive link between crop vigour and timely irrigation. There were observable differences in crop vigour and moisture retention on farms that were ripped, irrigated and had a cover crop. Those that lacked soil cover were more susceptible to rilling.

Managing soil cover

Cover crop

After harvest, a farm with pigeon pea is not grazed, since environmental bylaws restrict grazing on farms with crops. The land is left with cover until the next crop is planted.

Lablab and mucuna are either slashed or left to wither after harvesting maize. Farmers indicated that although mucuna has very few known benefits, it provided good soil cover and suppressed weeds on banana farms. However, mucuna and lablab need timely management to avoid coiling on crops and suppressing them completely. Farmers have learned how to make mucuna into a drink through training organized by the Asian Vegetable Research Development Centre (AVRDC).

Pigeon pea, and especially lablab, fetch high prices in the local market and in Nairobi, where a 120-kg bag of lablab sells for as much as USD 100.

In Sakila, pigeon pea is mainly grown as a cash crop; it is sold locally at markets in Kikatiti and Arusha town. Most farmers do not use it for home consumption. In other parts of the district, pigeon pea is a protein supplement and source of food and firewood. Pigeon pea adoption is on the increase, especially the short-lived species. Lablab is also a food; the beans are cooked, both green and dry, and the tender leaves are edible. Lablab is relatively drought resistant. It has also become a good source of income.

> Mama Temu planted maize intercropped with pigeon pea in 2005. In July she cut the maize tops after maturity to reduce shade on the pigeon pea. She harvested the maize in August. In September, pigeon pea beans were harvested and the plants were left for the whole year into 2006. She formed an improved fallow or rotation system on her land. She also managed to reduce weeding and increase water retention. The next pigeon pea harvest will be this September. Pigeon peas give good soil cover because it has a dense canopy. She plans to plant maize in the following season. This way farmers keep harvesting pigeon pea, and it forms a canopy for soil cover and suppresses weeds.

Crop residue

Crop residue can be soil cover. Most mulch is from maize stover, bean straw, banana leaves, coffee leaves and soybean residue. According to FAO (2002), for crop residues to be effective, approximately 70% of the soil surface must be covered by mulch. Mucuna and lablab provide the best soil cover and have a lot of organic matter from numerous large leaves. They provide 50–80% soil cover. In almost all farming, managing residue is controversial. There is never enough residue for conserving soil moisture, increasing soil organic matter, improving water infiltration, protecting soil structure, and for providing fodder, fuel, handicrafts, thatching and fencing. The most controversial use of residue is for livestock fodder during dry periods. Most farmers agreed that during the dry season, one has to balance between the soil and the livestock, obviously giving livestock priority. However, farmers who conserve soil grow fodder along contours, and it can be used as feed.

Maize stover and bean residue are usually slashed, stored on the homestead, and fed gradually to animals. The stover not eaten by the animals and the manure are taken to the nearest farm, not necessarily the farm from which the residue was removed. Soil cover has had minimal impact on managing weeds because farmers fed it to animals. Farmers who were able to maintain soil cover saw soil moisture retained, soil organic matter increased and water infiltrated.

Pastor Humphrey adopted conservation agriculture and planted fodder crops for his cattle. In 2005, he ripped his two acres and planted maize intercropped with lablab. During this season he had to untangle the lablab from the maize. After harvesting the maize, he left the maize and lablab residue on the ground. Later in the year he ripped in the same furrows and planted maize, but, due to the heavy rains, he was not able to plant lablab on time. The maize plants shaded the lablab. Therefore, to attain good soil cover from cover crops timing is still critical.

Socio-economics

Gender

Women have requested land as they want to practie conservation agriculture. In most cases they have succeeded and are supported by men in getting oxen and in ripping. Women can borrow oxen during the dry season and because the implements are lighter, they can prepare and rip land—formerly mainly a man's task—well before the rains (Mwalley and Rockstrom 2002).

With the growing urbanization in Arusha, young people still prefer to look for jobs in town, buying and selling merchandise, rather than staying home and farming. This limits labour during cropping season.

Relationships between farmers

Early adopters were not well understood by the community, especially when preparing land. The community worked hard ploughing and cleaning land for sowing, while conservation agriculture adopters either sprayed herbicides or slashed weeds to plant in unploughed land. The most controversial issue is controlling livestock grazing. As Thomas, an early conservation agriculture adopter, put it, 'They did not understand us when we refused to give out the crop residue and left it on the fields and, at the same time, refused to let animals come into the farms after harvest.' This led to hostility. Neighbouring farmers grazed the farms at night. The conservation agriculture farmers had to guard their farms to maintain soil cover. Gradually, after Thomas managed to rehabilitate his land by constructing contours and rotating maize and lablab or pigeon pea, other farmers came to understand. Farmers who did not weed by turning the soil but just scraped or roughed the weeds surprised their fellow farmers.

> Mr Chondo helped his wife by convincing the village water committee that she needed to irrigate their conservation agriculture farms; she had planted maize and lablab on one farm and maize and pigeon pea with ripping on another.

Conservation agriculture has unsettled conventional farmer preconceptions, since these farmers did not practise the norm. This has led some conventional farmers to try out the technology, especially those in field school groups. It will most likely take longer for most farmers to adopt feeding animals dry feed in zero-grazing unless there are active community awareness campaigns and bylaws are established and enforced in a participatory manner.

Adoption

Many people are reportedly migrating to the newly established Kilindi District, in Tanga Region, about 85 km south-east of Arusha, in search of land. This affects the continuity of conservation agriculture in Arumeru District because some conservation agriculture farmers are also moving. The youth, between 20 and 35 years old, do not find agriculture enticing and most have moved to Mererani, an area where tanzanite is mined, or to urban areas to start small businesses. However, the young are willing to adopt conservation agriculture because it reduces labour. The elderly likewise appreciate the reduced labour and increased yield, but they cannot afford certified seeds, herbicides and implements. Though some farmers have been practising conservation agriculture and even purchased herbicides for no-till operations, about 40% have never heard of conservation agriculture implements. This means that conservation agriculture needs to be promoted and scaled up more vigorously.

Land tenure

Land tenure is of prime importance for sustainable agriculture. Only those who own or have secure access to their land for a long time are interested in maintaining it. In Sakila, most land is acquired through inheritance; each farmer has an average of one to two acres. A small-scale farmer who rents land every season is vulnerable to the owner's demand and change of mind.

Large-scale farmers, with land leases for 33–99 years, can invest in long-term conservation agriculture, knowing it will ultimately benefit them. They also can get loans to invest in agricultural operations.

Farmers have benefited from reduction of labour and increase in yields, which mean more food in the household. Cover crops like lablab and pigeon pea are food crops that contribute a lot to farmer income.

The group at the Manyire Farmer Field School harvested a good crop in 2005. The landowner has been observing the conservation agriculture practices being carried out on the plot he has rented to the school. He has seen the difference between those crops and the crops on his farm. Now he is reluctant to rent to the farm school the next season. According to Nill et al. (1996), the traditional heritage system favours extensive land fragmentation, which obstructs adopting conservation practices. Land owned by the parent is divided among the children, especially the male children, affecting long-term conservation practices. The head of the household decides how to manage the two acres and who lives on it.

However, a few farmers do practise conservation agriculture on rented farms. Hilda Chondo ripped her rented land a second time in two seasons, while Pastor Humphrey added acreage by renting and planting two more acres under a pure lablab stand.

Economic benefits

In Manyire, lablab was initially shunned. It was a new crop and farmers did not value it. However, after one year, the whole village sought lablab seeds for the 2005 sowing season. Lablab was profitable. It increased incomes. Farmers who planted lablab in 2003 fetched up to TZS 100,000 per bag. In 2005, lablab was planted in abundance. Nelson Martin, a pastor in Manyire Village, said, 'I planted 10 kg of lablab as a cover crop with maize. I harvested 300 kg and all was sold. I got TZS 300,000 and used it to finish building the family house.' In 2006, he planted 13 more acres of lablab. Other farmers were expecting to reap similar benefits.

8 Gaps and challenges

Low adoption

Conservation agriculture was mainly promoted through a few farmers in selected villages, principally as minimum tillage. Most projects lacked continuity and were phased out without sustainable strategies. Conservation agriculture is mainly practised where conservation agriculture organizations had projects in place. Instead of the practices spreading to other areas, they are done on a minimal scale. Projects and organizations preferred to use similar sites, leading to duplicating techniques on an area with little spreading to other parts of the district.

Affordability

Some farmers see the initial cost of practising conservation agriculture—new implements, cover crop seed and herbicides—as expensive, despite the benefits. Conservation agriculture increased demand for animal power. Those without draught animals will have to rent or acquire them. They are a main source of power for most of the implements. Poverty is exacerbated by diseases, such as malaria and HIV and AIDS, which render able people helpless and cost them their meagre resources to try to sustain their health.

Land tenure

Small-scale farmers willing to practise conservation measures need entitlement to land for more than one season to see improved soil fertility.

Few conservation agriculture implements

Conservation agriculture implements were not readily available. Most of the rippers were recalled, leaving farmers with no choice but to revert to conventional tillage. The rippers were too few. In some cases, they were shared among stakeholders and institutions.

Lack of follow-up and coordination

Conservation agriculture initiatives lacked coordination on implementation, up-scaling, documentation and evaluation. After projects phased out, little was documented on the results of using the technology.

Inadequate conservation agriculture skills

Government extension staff serve vast areas, though they are expected to be in touch with farmers regularly. They are hindered by lack of adequate facilities. At the same time most are not aware of conservation agriculture, leaving the responsibility to the few with extensive knowledge. Yet they could greatly contribute in spreading and monitoring conservation agriculture as a daily duty. Conservation agriculture is a new technology and the knowledge needs to be widely spread to enhance its adoption.

Bylaw enforcement

Grazing bylaws were weakly enforced by local governments, leading to continued soil degradation, competition with livestock for crop residue and loss of soil cover.

Migration

Migration out of the district to the newly established districts affected the development of conservation agriculture. Conservation agriculture knowledge was not widespread and few were aware of it.

Adequate soil cover and weeding

The cover crops had many uses, so adequate soil cover was not attained. This was exacerbated by drought, pests and diseases, and competition for livestock feed. Consequently, soil cover did not greatly reduce labour for weeding.

Diversity of crops for research

Maize has been the main crop used for research. Other crops needing conservation agriculture intervention are irrigated horticultural crops, barley and wheat, especially with conservation agriculture implements, which are not available in Tanzania.

9 Conclusion

Conservation agriculture is a good way to farm, reduce soil erosion, and increase water infiltration, soil organic matter and, ultimately, food security. It requires radical change in farmer and extension staff attitudes. This requires patience and combined effort from all stakeholders involved in conservation agriculture.

Practical demonstration of success through good yield is essential to increase adoption and improvement in the standard of living. When farmers who adopted conservation agriculture build a new house or repair an old one, it captures the attention of neighbours, who may decide to adopt conservation agriculture to gain the benefits. The efforts of the successful farmer are not acknowledged—but copied secretly.

Farmers have been able to select and use different aspects of conservation agriculture, enabling them to see it as friendly and adaptable. Some farmers started with one practice—reduced tillage or rotation or intercropping cover crops with main crops—and ended with planting pure stands of lablab. In almost all cases, farmers started on a small portion of their land, then expanded it after every season.

Conservation agriculture practices in Arumeru District are still at an initial stage, especially for small-scale farmers. The practice started almost entirely through SARI in Arumeru. Although the technology supporting its principles existed, SARI did not sustain its effort by moving from demonstrations to farmer plots. Currently, SARI works with a wide network of community organizations, NGOs and private businesses. Sustainable agriculture and soil conservation were disseminated mainly through farmer innovators, who were supposed to pass on the knowledge acquired, which often did not happen. The farmer innovators themselves can still be identified through their practice and knowledge, but few have learned from them. However, diffusion through the farmer groups has taken place quickly. This has led to spontaneous conservation agriculture adoption and upscaling in plots, villages and institutions, mainly with rippers, jab planters and cover crops.

A lot of soil erosion still needs to be addressed in the lowlands. Soil erosion was reduced on trial plots with ripping and cover crops. Government agricultural offices will have to actively advocate attaining the recommended minimum of 30% soil cover. It will reduce labour and increase some yields. Conservation agriculture is an appropriate intervention for small-scale farmers burdened by disease, low purchasing power, low productivity, low soil fertility and food insecurity.

10 Recommendations

- Most conservation agriculture was tested under normal rainfed agriculture conditions. Since the rains are not dependable, conservation agriculture initiatives need to diversify to suit different situations, such as irrigation and vegetable farming. Crops used in trials should involve crops other than maize.
- Herbicides should be used in a manner that the farmers can manage with the aim of gradually moving away from them. Information on managing

and handling herbicides should be disseminated to farmers to avoid waste and negative effects.

- The government has a major role in improving agriculture in the district by helping villages form and enforce bylaws to maintain a sustainable environment.
- Most extension staff need to be brought up to date with conservation agriculture technology and spread it. Best practices learned from projects can be used in promoting, guiding and sustaining initiatives for farmers.
- Total, not partial, involvement of farmers in developing technology should be participatory. Past approaches in an area should be evaluated before introducing new practices.
- Many poor farmers use draught-animal power. Integrating cropping with animal production is essential for sustainable rural livelihoods and enhancing conservation agriculture, especially maintaining soil cover. Animals produce manure, adding value to the land, and eat crops and crop by-products.
- Conservation agriculture should be integrated with previous practices, such as soil and water conservation and agroforestry. The highlands of Sakila need contours and Ngorbob and Likamba villages need to reclaim land to sustain food security and livelihoods.
- Conservation agriculture institutions should spread the technology to new areas in the district to avoid localizing information and efforts. This will also contribute towards having widely available literature and reports about conservation agriculture in the district.

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Appendix 1 Conservation agriculture institutes and projects

Organization	Activities	Methods to promote conservation farming	Links with other organizations
District Agriculture and Livestock Extension Office, Ministry of Agriculture	Provide extension to promote fertilizer, improved seeds, improved dairy cow breeds, improved milk processing, contours and trees, cover crops and legumes Under Conservation Tillage Project, promote technical package of obligatory contour construction, draught-animal ripping, chemical fertilizer and weeding	Assist in coordinating the Conservation Agriculture and Sustainable Agriculture and Rural Development project and other conservation agriculture initiatives in the district Technical assistance and support provided by ward and village extension officers	SARI, TFSC, NGOs
Selian Agricultural Research Institute (SARI), Arusha	Research, develop and diffuse subsoiling and no-till with cover crops Support from FAO, GTZ, IFAD, TFSC	Farm and non-farm trials Demonstration plots Training Field days Provide cover crop seeds Promote no-till equipment	TFSC, WADEC, extension
Centre for Agricultural Mechanization and Rural Technology (CAMARTEC), Arusha	Develop, adapt, and disseminate appropriate technology in agricultural mechanization (mainly ox implements), water supplies, sanitation, low-cost housing, rural transport, alternative energy and postharvest equipment Responsible for mandatory testing all agricultural equipment Parastatal organization under Ministry of Industry and Commerce	Produce more than 150 jab planters	
Tanzania Engineering and Manufacturing Design Organization (TEMDO)	Applied engineering research and development institute Design and manufacture manual and powered postharvest equipment In process of being privatized, but currently salaries received from Ministry of Industry and Commerce	Produce 10 Magoye rippers and subsoiler for SCAPA Opportunity: Brazil-type no-till animal-drawn planter drawings for tender in Tanzania	SCAPA
Heifer Project International	Improve integrating crops and livestock by establishing fodder and providing dairy cattle	Establish fodder, reduce competition on cover crops and crop residue	

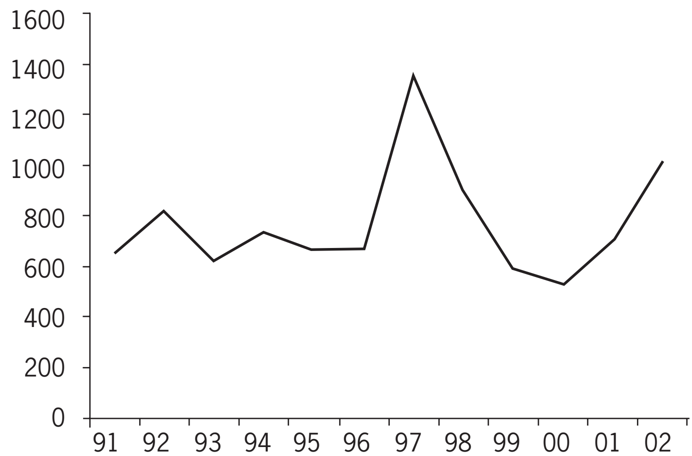
Organization	Activities	Methods to promote conservation farming	Links with other organizations
National Livestock Extension Project (NALEP-I and NALEP-II, 1995–2001)	Improve agricultural practices, build extension staff capacity Train VAEO Supply transport to extension staff Supply stationery	Build capacity and motivate extension staff	World Bank–sponsored project
Conservation Agriculture and Sustainable Agriculture and Rural Development (CASARD)	Promote conservation agriculture with small-scale farmers	Farmer field schools Train artisans	Pilot with SARI in collaboration with GTZ/TFSC, ACT, SFI, FAO, IFAD
Research, Community and Organizational Development Associates (RECODA)	Promote lablab, mucuna, soybean, banana Promote minimum tillage with cover crops Control gullies, promote animal power, agroforestry	Provide mucuna, pigeon pea, lablab seeds Provide improved maize seeds Field days and training Introduce minimum till implements Establish tree nursery, importance of agroforestry	SARI, government, NGOs
Soil Conservation and Agroforestry Programme in Arusha (SCAPA)	Conservation tillage: subsoiling, draught-animal ripping, mulching, cover crops, using farmyard manure, row spacing and fertilizer Contour bunds and fodder grasses, tree spacing, gullies rehabilitated, gender, fish farming, beekeeping, horticulture, water-harvesting structures, managed grazing, improved stoves Funded by Swedish International Development Cooperation Agency (Sida) and supported by RELMA	On–farm demonstration trials in Arusha and Arumeru Districts Collect data and analyse though field days Import draught-animal rippers from Zambia through TFA Community development officer organizes farmer groups to use ripper to subsoil, mulch and plant cover crops and use manure Study tours to Machakos in Kenya	TFA

Organization	Activities	Methods to promote conservation farming	Links with other organizations
Tanzania Farmers Service Centre (TFSC)	Tractor subsoiling and ploughing, combine harvester hire services Sell agricultural machinery and spare parts Service agricultural machinery Support conservation agriculture research, training and demonstration trials Hold workshops and courses on sustainable agriculture, using agricultural machinery and efficient crop production Initially supported by GTZ, now self–funded; retain a development mandate	Collaborate with SARI demonstration plot with cover crops, minimum and no-till Provide machinery for demonstration trials, seeds and expert support Promote tractor subsoiling services to farmers (TZS 60,000 per acre)	SARI
Tanganyika Farmers Association (TFA)	Supplies: seeds, fertilizer, pesticides, fungicides, hand tools, draught-animal equipment, sprayers Branches throughout country Membership fee TZS 15,000: discount on purchases, access to credit, share in dividend, free advice	Sell to members (on credit) and non-members Sell draught-animal rippers by Nandra Engineering at Babati depot Opportunity: display lablab seeds to create awareness	Manufacturers and suppliers
Nandra Engineering Ltd, Moshi	Manufacture draught-animal rippers, spare parts for rippers and tractors on request Manufacture maize mills, hullers, grain storage tanks, coolers, water tanks	Facilitate group purchases on credit Spare parts for rippers and tractors direct from workshop or shop in Arusha Opportunity: manufacture no-till direct planter, jab planter	Land Management Project (LAMP) Babati (rippers), Conservation Tillage Project (rippers)
CIMMYT (2005)	Promote conservation agriculture in maize Provide lablab to farmers	Trials with cover crops and ripping	SARI
Women's Agriculture Development and Environmental Conservation (WADEC)	Agroforestry techniques in soil and water conservation Build contours Establish tree nurseries Sell tree seedlings	Provide cover crops and training	SARI

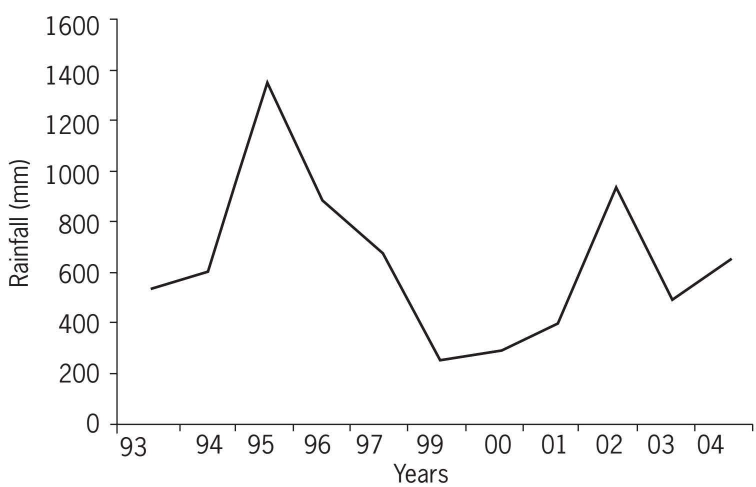
Organization	Activities	Methods to promote conservation farming	Links with other organizations
FARM Africa	Supported by EU and Netherlands Grants to other NGOs for sustainable agricultural initiatives	Work with local NGOs to provide no-till implements, rippers Train farmers	SCAPA, FNDAT

Appendix 2 Rainfall graphs

Rainfall trends in Olmotonyi station, 1991–2002



Rainfall trends in Airport station since 1993–2004



Appendix 3 Lablab and mucuna seed distribution

District or region	Lablab seed (kg)	Mucuna seed (kg)	Donor or source
Arumeru District	600	200	FAO, CASARD
Arusha District	200	120	Individual farmers
Babati District	300	—	Individual farmers
Kilimanjaro Region	100	—	District council
Simanjiro	600	—	District council
Simanjiro	100	—	From Mbauda market
Farmer visitors to SARI	150	80	Individual farmers
Government workers in Arusha	160	—	Individual farmers

Source: SARI

Appendix 4 Cropping operations in Arumeru District

Activity	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Long-season rains				x	x								
Prepare land. Tools: tractor plough, hand hoe, mouldboard plough	x	x											
Ripping	x	x	x										
Plant. Tools: hand hoes, direct planter, mouldboard plough, jab planter (minimal use)													
Maize			x	x	x								
Beans				x	x								
Lablab (2 weeks after main crop)			x	x	x								
Pigeon pea (together with main crop)			x	x	x								
Weeding (1st and 2nd)					x	x							
Untangle lablab on maize						x	x						
Apply fertilizer, manure (not common for food crops)													
Harvest crops													
Maize									x				
Beans							x						
Lablab									x	x			
Pigeon pea										x	x		

Karatu District

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Abbreviations

ACT	Africa Conservation Tillage
AIDS	acquired immunodeficiency syndrome
CA	conservation agriculture
CAMATEC	Centre for Agricultural Mechanization and Rural Technology
CA-SARD	Conservation Agriculture for Sustainable Agriculture and Rural Development
COPEC	comprehensive participatory environmental conservation
CTP	Conservation Tillage Project
DALDO	district agricultural and livestock development officer
DAP	draught-animal power
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field school
FGD	focus group discussion
GOT	government of Tanzania
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
HIV	human immunodeficiency virus
IFAD	International Fund for Agricultural Development
IIIWCCA	Third World Congress in Conservation Agriculture
KDA	Karatu Development Agency
KDC	Karatu District Council
MBK	Mazingira Bora Karatu
NALEP	National Livestock Extension Project
NRM	natural resource management
PADEP	Participatory Agricultural and Empowerment Project
RECODA	Research, Community and Organizational Development Associates
RIDEP	Regional Integrated Development Programme
SARI	Selian Agricultural Research Institute
SFI	Soil Fertility Initiative
SLM	susainable land management
TAF	Tanzania Association of Foresters
TEMDO	Tanzania Engineering and Manufacturing Design Organization
TFA	Tanganyika Farmers Association
TFSC	Tanzania Farmers' Service Centre
URT	United Republic of Tanzania
WWF	World Wide Fund for Nature

Units and measurements

1 acre = 0.405 ha
1 ha = 2.47 acres

Karatu acknowledgements

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We give special thanks to Dr David Watson for his contribution in this work. He visited the study area to see the reality on the ground and gave constructive criticism and inputs, which enabled us to give this report shape.

We extend our thanks to Karatu District Council, particularly the agricultural department, for its assistance during fieldwork and interviews. They were available when needed and responded well to our questions. We appreciate the participation of farmers. Their dedication and free sharing of information contributed a lot to this report. It is our hope that the results of this study will contribute meaningfully to improving conservation agriculture technologies and practices.

Many institutions agreed to be interviewed. We appreciate the participation of Nandra Engineering Moshi, Tanganyika Farmers Association, Karatu Development Agency, Tanzania Association of Foresters, Ngorongoro Conservation Area Authority, Heifer Project Tanzania, Centre for Agricultural Mechanization and Rural Technology, Tanzania Engineering and Manufacturing Design Organization, Canadian Physicians for Aid and Relief, and Msituni Farm.

Executive summary

A case study was undertaken to establish experience with conservation agriculture in Karatu District by documenting its practices, achievements, challenges and gaps, and future aspects of these technologies in the study area. The study employed a wide range of methods: literature review, interviews with key conservation agriculture stakeholders, field visits, participatory rural appraisal workshops and focus group discussions.

For a long time in Karatu crop production by small-scale farmers has been performing poorly, primarily due to inadequate rainfall, shortage of labour, drudgery because of using inefficient implements like hand hoes, and declining soil fertility and productivity due to nutrient mining, soil erosion, depletion of organic matter and destruction of soil structure leading to the formation of hardpan. Climatic conditions have become increasingly unpredictable; precipitation has become highly erratic and the area has been subject to increasingly longer dry periods. On-site effects of soil erosion include the loss of fertile topsoil and large fluctuations in the flow of rivers and springs, leaving behind degraded terrain. Degraded land stores less water, making crops vulnerable to drought, and it has a serious negative effect on the supply of water into Lakes Manyara and Eyasi. Off-site effects of soil erosion cause pollution of water bodies, sedimentation on farmlands, and physical damage to crops and infrastructure. There is serious concern over the increase of sedimentation in Lake Manyara, which is reducing the water depth and exposing more water to evaporation. The environmental degradation in Lake Manyara National Park, one of the famous tourist sites in Tanzania, may affect wildlife.

Workforce for farming has been declining over time as many youth find the system used by small-scale farmers tedious with little returns and opt either to migrate to towns or to remain jobless in the village, loitering and becoming a drunkard. The HIV/AIDS epidemic has also affected the labour supply significantly.

Among the conservation agriculture practices in use are subsoiling, that is, using a Magoye ripper to break hardpan. Direct seeding in planting is done with jab planters or hand hoes while crop rotation with lablab and wheat is practised. Some indigenous conservation agriculture practices include planting pigeon pea and pumpkin as cover crops. Cover crops such as *Dolichos lablab* and *Mucuna* are intercropped or relayed with maize as a main crop. Practices aimed at conserving soil include establishing contours, especially on sloping areas, and agroforestry techniques for soil and water conservation.

The main driving force for introducing conservation agriculture principles was the need to increase yield per unit area as yield continued to decline year after year. Research findings revealed that soil productivity was the most limiting factor where soil hardpan and low organic matter disrupted the soil structure, ultimately resulting in low moisture-holding capacity and microbial activities. Conventional methods of cultivation and the use of inorganic fertilizers did not solve much.

The conservation agriculture entry point in Karatu aimed at counteracting the drought circumstances by using draught-animal power and ripping through to break the hardpan and at the same time instituting in situ rainwater harvesting, considered a labour-saving technology.

Forces driving for adoption of conservation agriculture include success stories around the world, research findings, results from early adopters showing benefits in soil fertility improvement and increased yield with reduced labour and other costs of production, and government policies supporting conservation agriculture technologies and practices. Project support in conservation agriculture inputs, knowledge and various incentives promoted adoption. Conservation agriculture pathways, which are referred to as the adoption process, were based on the purchasing power at household level, land size, existing indigenous technologies compatible with the introduced conservation agriculture practices, multiple uses of cover crops, and group formation and dynamics such as farmer field schools.

Some conservation agriculture successes recorded from the study area include increased yield in beans from an average of 2–3 bags to 5–7 bags per acre, and maize from 5–7 bags to 15 bags per acre. Rippers and subsoilers have also improved water infiltration, enabling crops to tolerate dry spells. Conservation agriculture has also proved to be a labour-saving technology as fewer operations are required compared with conventional agriculture. Households that have adopted no-till no longer need to slash and burn their trash or plough and harrow their fields. The reduction of weeding operations has been of great relief to farmers, especially women. Using lablab as a cover crop has resulted in multiple benefits such as suppressing weeds, controlling soil erosion and improving soil fertility. It is also used as a cash crop, has edible seeds, and is available as a green vegetable during the dry season.

Despite the success of conservation agriculture principles in improving crop production, there are many challenges to overcome, as the concept seems to be 'new' in many farming systems. Among the problems are the need to change farmer perceptions and mindset and to make inputs more readily available. Unpredictable weather conditions, inability to maintain a permanent soil cover, limited knowledge, and livestock keeping are retarding efforts to make conservation agriculture taken up more widely. Many projects have not proved sustainable in the long term, slowing the diffusion of conservation agriculture technologies. Inadequate coordination of conservation agriculture activities at district level due to the limited number of extension staff and knowledge of how best conservation agriculture can fit in different systems have also posed problems. Conservation agriculture implements are not readily available at district headquarters, and some are too expensive for the purchasing power of most farmers. Few initiatives have focused on policy analysis or on advocating that conservation agriculture technologies be included in national agricultural policies and that whenever possible each district have a resource centre to deal with such technologies, inputs and implements.

Suggestions have been made on ways to overcome challenges that include coordinating conservation agriculture stakeholders towards a common focus in achieving set goals, establishing a database of conservation agriculture activities and references, creating awareness and sensitizing the community about conservation agriculture, analysing policy and advocating that conservation agriculture technologies be included in the national agricultural policy, and encouraging that a conservation agriculture programme rather than conservation agriculture projects be undertaken. Conservation agriculture manuals need to be translated into local languages in simple phrases. The conservation agriculture package of technologies should integrate livestock with crops.

1 Introduction

Tanzania's agricultural development plans aim to stimulate and facilitate sustainable production in the smallholder farming systems (URT 2000). The government's priority is to introduce participatory technologies that are environmentally and socially acceptable and that can sustainably ensure poverty alleviation, and food and nutritional security. Planning, coordination and implementation of development plans in Tanzania are all highly decentralized. Government authorities in the district have this responsibility, and so do key stakeholders in planning and implementing agricultural programmes. At the grassroots some agricultural project activities are facilitated by non-governmental organizations (NGOs), community-based and faith-based organizations, and some local initiatives.

Agricultural plays an important role in the economy of Tanzania as it contributes significantly to the country's GDP; it accounts for 60% of export earnings and employs 84% of the rural population. Crucial components of the agricultural sector are food crops, at 55% of the total agricultural GDP, livestock at 30%, and traditional export crops at 8% (URT 2004a).

For many years, the agricultural production of small-scale farmers has generally been low, constrained by low soil fertility, erratic and unreliable rainfall, and poor production techniques (Shetto 1998). According to Elwell et al. (1998), agriculture in Tanzania is characterized by extensive ploughing, which has proved to be one of the major causes of land degradation.

Many interventions have been introduced in an attempt to solve these problems; most have had zero or at best marginal impact on the livelihoods of small-scale farmers (URT 2001). Technologies introduced in the district include contour cultivation, use of inorganic fertilizers, agroforestry (improved fallowing), and organic farming. Since the late 1990s, several agricultural researchers and extensionists have been considering conservation agriculture as an alternative that can improve the livelihoods of small-scale farmers through improved crop production. The GTZ/TFSC project with its conservation tillage, cover crops and subsoiling components started in 1996 with the Selian Agricultural Research Institute (SARI). In January 2000, FAO supported a visit by a team from Brazil to Karatu. The team, which also came with a few jab planters and the no-tillage seeder, discussed and presented the Brazil conservation agriculture model. The IFAD/FAO study on saving labour, with focus on reduced tillage practices and use of cover crops, started in October 2002 in Karatu. SARI has been keen in most of the conservation agriculture interventions in the northern region.

Conservation agriculture aims to conserve, improve and make efficient use of natural resources through integrated management of soil, water and biological resources. It has the potential to increase crop production while simultaneously reducing erosion and reversing declining soil fertility, improving rural livelihoods and restoring the environment (FAO 2000). The fundamental principle of this technology is to achieve sustainable soil productivity through rotating crops, reducing disturbance of the soil structure, protecting soil from direct climatic effects such as solar radiation, rain and wind, enhancing water infiltration, and building up soil organic matter and soil organisms.

Despite the soundness of conservation agriculture principles in improving crop production, there are many challenges to overcome before conservation agriculture becomes a reality in Karatu. This case study documents experiences of conservation agriculture in Karatu District—its practices, achievements, challenges and gaps, and future prospects for it in the study area.

2 Study objectives

General objective

- To develop a deeper understanding of the experiences of conservation agriculture in Karatu District.

Specific objectives

- To document the biophysical, socio-economic and institutional environment of the study area
- To give a history of conservation agriculture–related work together with an overview of conservation agriculture adaptation, diffusion process and impact
- To present gaps and challenges in conservation agriculture technologies
- To document key issues in conservation agriculture, that is, labour, biomass management and suitability of conservation agriculture under different biophysical conditions

3 Method

The Karatu case study began with the formation of a local case study team by integrating representatives from the Selian Agricultural Research Institute (SARI), RECODA (Research, Community and Organizational Development Associates) and the agricultural department of the Karatu District Council (KDC). Briefing meetings included training, discussion of the framework and questionnaires, and allocation of specific duties.

Relevant institutions were identified as key sources of information, and a list was drawn up of the type of information each institution was expected to provide. Selection of institutions was based on their being involved in soil and water conservation, agricultural input supply, or manufacture of agricultural implements, and in improving crop production through research and extension services. Among the institutions earmarked and visited were SARI, Tanzania Farmers' Service Centre (TFSC), Heifer Project Tanzania, Karatu Development Agency (KDA), Ngorongoro Conservation Area Authority (NCAA), Tanzania Association of Foresters (TAF), Centre for Agricultural Mechanization and Rural Technology (CAMATEC), Tanzania Engineering and Manufacturing Design Organization (TEMDO), Nandra Engineering Moshi, Mazingira Bora Karatu (MBK), and Canadian Physicians for Aid and Relief. The institutions were visited to relate their activities with sustainable agriculture and conservation agriculture improvement in Karatu District.

To get insight information on conservation agriculture technologies in Karatu, key informants interviewed were people responsible for improving agriculture and environment (conservation), farmers practising conservation agriculture, farmers who once tried conservation agriculture and abandoned it, and those who chose not to practise conservation agriculture even though they'd had the opportunity to do so. A key informant discussion was conducted mainly with selected extensionists, SARI staff, Karatu agricultural officers and leaders of the organizations facilitating conservation agriculture practices.

Focus group discussions and workshops were conducted with villagers and members of farmer field schools (FFSs). Focus group discussions were conducted in the villages of Arusha, Ayalabe, Gyeknu Getamock, Gyeknu Lambo, Kilimatembo, Mbulu Mbulu, Rhotia Kati, and Tloma. The focus groups in each village included village government members, sub-village leaders, and scores of any readily available ordinary villagers.

Field sites to visit were identified to see the different conservation agriculture practices in situ. Observed practices include intercropping pigeon pea and maize or sunflower, *Dolichos lablab* as a pure stand or intercropped with maize, contour cultivation, and agroforestry practices. Information was collected through discussion with representatives from different stakeholders working to improve agriculture. Field observations were made of individual small-scale farmers practising conservation agriculture and those not practising. In addition, large-scale farmers were visited: Gibsi Farm dealing with coffee production and agroforestry, and Msituni Farm. Photographs were taken to enrich the written information. All information and data were brought together, synthesized, analysed and used to compile the report. The draft report was summarized and circulated to stakeholders.

4 Background information

General description of Karatu District

Location

Karatu is one of five districts in Arusha Region, located in the northern part of Tanzania (fig. 1). It became an administrative district in 1997. It is located south of the equator between latitudes 3°10'–4°00'S and longitude 34°47'E. Karatu District borders Mbulu District to the west, Ngorongoro District to the north, Babati District to the south-east and Monduli District to the east. It is the traditional home to the Iraqw tribe. Other minor tribes are the Bardaigs, who are pastoralists, and the Hadzabe, noted mainly as hunters and gatherers.

Area of occupation

The district measures 3300 km^2. Land use is classified as follows: arable land 102,573 ha; pastureland 155,808 ha; forest, bush and tree cover 61,218 ha; and Lake Eyasi 1060 ha. Karatu has 4 administrative divisions, 13 wards and 45 registered villages. The administrative headquarters in Karatu town. approximately 150 km west of Arusha town. It is an important stopover for most tourists heading for Ngorongoro and Serengeti National Parks.

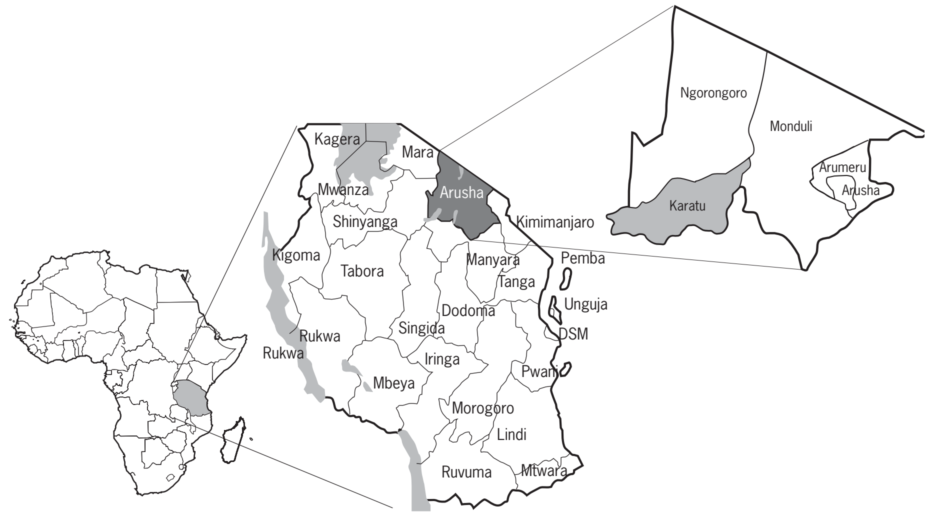

Figure 1. Map of Karatu.

Human population and demography

The official population of the district is 178,434 people: 92,895 men and 85,539 women, growing at an annual rate of 3.2% and aggregated into 33,000 households. The average population density is 52 person/km^2 with low densities in the western zone along Lake Eyasi (7–10 person/km^2) and higher densities (100 person/km^2) in Karatu and Mbulumbulu division (URT 2004b). Most people live in the higher rainfall areas where the average population density tends to be high.

Land physiography

Lakes Manyara and Eyasi in the district influence the climate through low and high pressure belt mechanisms, especially at the end of the dry season when winds blow vigorously, drying up the landscape and vegetation, and moving the clouds away from localized areas.

Based on relief, land physiography and drainage pattern, Karatu can be categorized into three zones—uplands, midlands and lowlands—with altitude ranging from 1000 to 1900 m. When entering Karatu District from Mto wa Mbu (Monduli District), there is a clearly defined escarpment in the Rift Valley, rising to more than 400 m. Lake Manyara and Manyara National Park occupy the plains at the bottom of the Rift.

At the top of the Manyara Escarpment in the highlands around Karatu, vegetation becomes more lush and green. The extinct, gently sloping Ol Deani volcano is a prominent feature of the landscape. In the past, the area around Karatu and Ol Deani was of great importance to the German colonial administration. The area's cool climate, fertile green hills, and pleasing views were popular with settlers and farmers. Extensive arable fields cover the slopes of the volcano and the land around Karatu town. Coffee was the main export crop, and a few large farms that remain in private ownership still cultivate the cash crop on the hills and valleys outside of town.

Climate

Rainfall

Rainfall in the district is bimodal; the short rains fall between October and December and the long rains ('masika') between March and June (KDC 2001) (table 1). Rainfall may range from less than 400 mm in the Eyasi Basin to over 1000 mm in the highlands with rain zones classified as semi-arid (300–700 mm/year) and subhumid (700–1200 mm/year) respectively. The wettest month is April. Rainfall varies considerably between years, especially in the semi-arid region, where the coefficient of variation of annual rainfall is 30–40% (Meindertsman and Kessler 1997). Duration and intensity of individual storms are unpredictable. Rainfall intensity can be very high, causing erosion, particularly at the onset of the rainy season when soils are bare.

Humidity and evapotraspiration

Relative air humidity increases during the rainy months from about 55% in October to about 75% in April/May (Meindertsman and Kessler 1997). Potential evapotranspiration measured at Karatu is about 1440 mm per year (average 120 mm per month). Evapotranspiration generally increases during the dry season, reaching a maximum in November just before the rains start. It is lowest at the end of the rainy season in May.

Table 1. Rainfall data (mm) 2000–2005

Month	Year					
	2000	2001	2002	2003	2040	2005
January	—	149.3	124.6	18.7	65.9	37.5
February	25	48.8	126.3	14.2	26.3	48.4
March	90.6	148.9	115.5	104	54.7	67.2
April	94.4	180.6	222.5	20.9	124	38.8
May	4.0	30.1	89.3	137	3.9	27.7
June	—	4.4	—	1.1	2.5	1.1
July	—	3.5	—	1.0	—	1.5
August	—	—	9.1	—	—	1.5
September	—	—	18.5	—	—	—
October	—	6.4	62.5	14.2	53.6	40.7
November	31.5	67.9	24.4	61.7	68.0	22.4
December	10.5	171.2	15.3	42.7	198.5	3.9
Total	256.0	811.1	808.0	415.5	597.4	320.7

Temperature

Temperature decreases with increasing elevation by about 0.6 °C for every 100 m. Mean annual temperature ranges from 15 °C in Nov forest to 24 °C at the level of Lake Eyasi. The coldest months are June–August, the warmest October–April. There are no frosts.

Winds

Wind velocity is generally highest during rainy season storms (Meindertsman and Kessler 1997). Wind moves from a high pressure belt (cold) in the high altitude of Karatu landscapes to the low pressure belt (hot) of low altitude in Eyasi basin (COPEC 2003). This climatic process, affecting all of Karatu District, causes great damage—wind erodes the soil and dries out the vegetation.

Natural resources

Areas of the district are rich in natural resources. On the north, the district borders Ngorongoro Conservation Area Authority, and to the south-east Manyara National Park extending to Marangu Forest Reserve. On the western part of the district is a vast area surrounding Lake Eyasi extending to Matala, rich in wild animals that attract tourists from all over the world.

The district has facilitated and built the capacity of grassroots communities in managing natural resources and their products by replanting trees in open areas and on individual gardens, introducing bee-keeping and fishing as well as reserving open wildlife areas. The community carries out forest-enrichment tree planting in water sources and catchments areas, and on hilltops and abandoned lands. Common tree species preferred and planted in Karatu include *Gravillea robusta*, *Senna* sp., *Jacaranda mimosofolia*, *Acacia codyla africana, Albizia* spp. and *Rauwolfia* spp. However, tree planting and growth are threatened by uncontrolled grazing. There are also deliberate efforts going on to reserve open wildlife areas to attract hunting and tourism in the wilderness, and to reinstate wildlife migratory corridors.

Practically all non-cropped areas have forest and grazing resources that are used for forestry, pastoralism and wildlife. Forest areas are located in the north-eastern part of the district. Dominating the study area are both bush and wooded grasslands, which occupy a large area of the central and southern zone adjacent to Lake Eyasi. Crops cover the higher altitudes of the north-east while grassland can be found in small portions of the central zone.

Soils

Soils vary depending on their origin and location. Shallow soils with low fertility are found on summits and slopes. Clay soils of moderate fertility are found in the valleys in gently rounded summits and on slopes overlying soft gneiss rocks.

Of volcanic origin are the predominantly clay soils, some very shallow but very fertile. Found in the Ngorongoro land system they include moderately steep foothill ridges of volcanic cones, lava plains and foothill slopes. Soils with recent ash deposits are rich in salts and are highly erodible.

Soils on the long, gentle slopes at the lower ends of foothills, scarp slopes and the flat plains of Lake Eyasi are mainly sand and clay, derived from basement gneiss and granite, but around Ol Deani volcano clays are derived from basalt by the action of wind, water and gravity. Fertility is low to moderate. This land system also includes most *mbuga* soils, in which evaporation causes sodium and calcium salts to accumulate.

Economic activities and marketing

Arable farming and pastoralism are the two kinds of land use. Crop and livestock production are by far the most important economic sectors, employing over 90% of the labour force in the district (Douwe and Kessler 1997). Farming is largely rainfed. Variation in soil, topography and climate determine land-use potential.

Apart from agriculture, tourism and associated businesses such as shops, hotels and restaurants are another significant source of income for the people of Karatu. The district encourages development of tourist hotels and campsites. In Karatu there are 6 tourist hotels and about 16 campsites (URT 2004b). Other local economic activities include producing beer and selling forest products such as charcoal. Though there is a demand for honey and other bee products, bee-keeping is underexploited as an economic venture. People still hang log hives from acacia trees in Ngorongoro forest. Modern hives have been introduced by agricultural and natural resources departments in the district council but their use is still very low.

Farms provide a significant source of income, especially during planting and harvesting, when many people are employed as casual labourers.

Crop production and mechanization

About 102,578 ha of the district's land area is classified as suitable for cultivation. The principal crops grown in Karatu include maize, beans and paddy (rice). Mbulumbulu and Karatu Divisions in the highlands produce wheat, barley, beans, maize, coffee, flowers, pigeon pea and safflower. Endabash Division in the midlands produces maize, beans, pigeon pea, sorghum, finger millet and sunflower. Previously, with adequate and well-distributed rainfall (> 800 mm), agriculture in the highlands was very productive but in recent years crop yields have declined, mainly due to unreliable rainfall (erratic precipitation and lower annual totals) and poor soil fertility (KDC 2001). Households have responded by diversifying into producing *Dolichos lablab,* finger millet, sorghum and short-term maize varieties, which are more drought tolerant. Maize and beans are primarily grown as staple subsistence food crops but in some high-potential areas in the highlands, they are both cash and subsistence food crops.

Improvements to crop production have focused on introducing improved varieties, replenishing soil fertility with inorganic fertilizers, controlling erosion, planting well timed and with proper spacing, and weeding. Maize intercropped with pigeon pea is the most common crop-production system in the highlands and midlands. In the lowlands agriculture is unsuitable unless irrigated. The most limiting factor in the lowlands is low rainfall: an average of 300 mm (Meindertsman and Kessler 1997).

Most of the surface and underground water sources in the district are seasonal, hence limited as potential for irrigation. However, permanent springs are found along Lake Eyasi in the Mang'ola flood plain. Potential area for irrigation in these plains is estimated to be 3600 ha, but the irrigated area is only 1081 ha.

The district has a good number of farm implements: 1700 tractors, 21 combine harvesters, 3900 ox ploughs, and a good number of draught animals (URT 2004b). Most of the tractor maintenance and repairs are done locally. Most operators are skilled in maintenance as most owners service or maintain their own tractors and equipment. Spare parts are available in Arusha town and installed in Karatu. Both large- and small-scale farmers own tractors while small-scale farmers own ox ploughs. Karatu District has one of the highest numbers of working tractors and combine harvesters in Tanzania. This has to do with the good soils and the possibility of farming wheat and other crops such as safflower. The tractors are relatively old (some tractors with more than 50 years) but still functional, signifying that farmers in Karatu have been able to make enough money to buy and sustain tractor use. This is a potential for the district in mechanization options under conservation agriculture (subsoiling, tractor direct-seeding implements, etc.). Large-scale farmers own tractors to work on their farms while small-scale farmers with tractors work with them on their fields and also hire them out to other farmers for ploughing or transporting. More than 40% of the farmers in Karatu have access to tractors for land preparation. During the low period of tractor activities, some small-scale farmers shift their tractors to other districts (Kondoa, Basutu, etc.) for business.

To some extent mechanization follows the agroecological zones; in the highlands where wheat and barley are mostly cultivated tractors are used for ploughing, harrowing and applying herbicides. Farmers also use combine harvesters for wheat and barley. Tractors pulling trailers are used to transport agricultural inputs and crops. Tractors are also used for disc ploughing, which is often done in combination with seeding maize with a person walking behind the tractor disc. Animal draught power is used for ploughing with a mouldboard plough. Oxen are normally used as a source of animal power, mainly for ploughing and transportation, while donkeys are normally used for transportation. Seeding is often done by hand behind the plough.

Land-holding size for households ranges from 5 to 15 acres (2–6 ha). Poor households with relatively small holdings of less than an acre and cultivating in the hilly uplands do most of the work by hand. The so-called onion hoe is used for planting by hand under minimum-tillage conditions, the work mostly done by women. Farmers with land size more than 2 acres can hire a tractor or animal power services, especially during land preparation, ploughing and harvesting. In 2006, the cost of hiring a tractor for ploughing an acre was around TZS 22,000[1] while hiring ox ploughing was about TZS 13,000. The price of hiring tractors has increased sharply with the increased fuel prices. Weeding is also often done with hired labour or in labour-sharing groups.

Both tractors and oxen ploughs are used in the midlands zone. In the lowlands, oxen provide draught power for ploughing and opening furrows for planting maize, sorghum and pigeon pea (fig. 2).

1 1 USD = TZS 1200 at time of survey

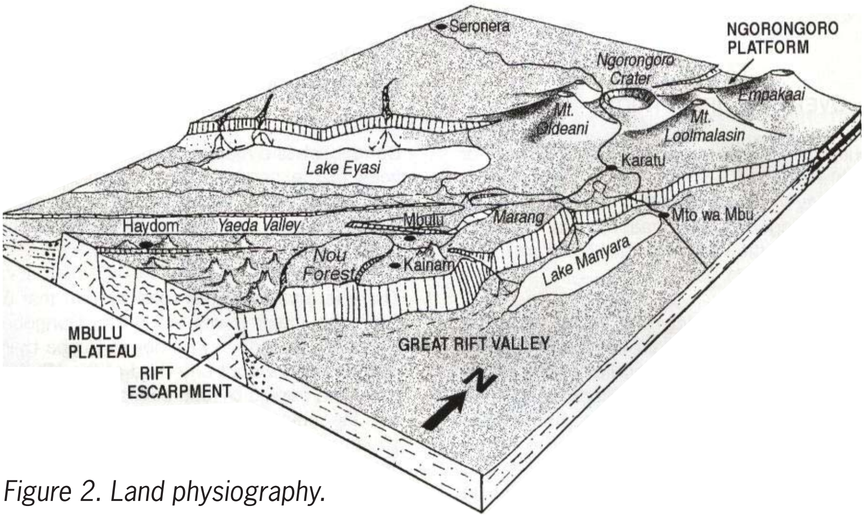

Figure 2. Land physiography.

Livestock production

Animals kept in the district are mainly indigenous cattle (149,242), dairy cattle (2892), goats (239,052), dairy goats (100), sheep (43,961), indigenous chickens (62,062), pigs (8836) and donkeys. An average of 7.5% of the population engages only in livestock keeping, the Barbaigs being the pastoralist community (URT 2004b). About 90% of the households engage in mixed farming. Crop–livestock integration helps farmers minimize risk and recycle nutrients. Crop residue is used as animal feed and in turn farmyard manure is applied on the field to improve soil fertility. Donkeys and oxen are used for cultivation and transportation. Heifer Project Tanzania has been promoting zero grazing and improved dairy cattle and goats in the area (HPT 2002).

Interventions by Heifer Project Tanzania resulted in increased milk production of approximately 10 litres per cow per day, which ironically resulted in marketing problems during the season of peak milk production. While free-range grazing is still practised, in many areas it is decreasing in popularity. Additionally, there are bylaws prohibiting free-range grazing though they are weakly enforced.

Due to land scarcity, it is increasingly difficult for pastoralists to find adequate open grazing land for their livestock. Village governments try to balance the need for land between crop farmers and pastoralists and to minimize conflict by allocating areas where pastoralists can graze their livestock.

Marketing

Agricultural business is current operating under a free market system. Prices have to be negotiated and this has disadvantaged farmers, who are no match for private traders, who skilfully negotiate low prices. Prices may be extremely low during the peak season but could also be high during the off season. Sometimes during a year of bumper yields, farmers are forced to sell their crops at cheaper prices because the crop does not store well. But when food is scarce produce fetches high prices. Under the current system of free marketing, while there are always buyers, prices are often extremely low, especially at the farm gate where the price can be a half of what is obtained from markets in town centres. For example, farmers sold lablab seed at the farm gate for TZS 45,000 while in Arusha market it was sold at TZS 100,000 (pers. comm. with farmers). For most farmers, the only reliable outlets for their produce are traders who collect produce directly from the farmers for sale in major urban centres such as Karatu and Arusha. The Rift Valley Co-operative Union (RIVACU), a buyer of agricultural produce, failed to offer competitive prices under free marketing systems, leading to its collapse.

Farmers also sell surplus produce during the open market day (*gulio* or *mnada*), which is held on every seventh day of the month. Some produce such as onion is sold not only in the Arusha region but also in Dar es Salaam and in neighbouring countries like Kenya (URT 2004b). Crops such as pigeon pea are collected in Arusha and exported to India.

There is a distinct need to develop a reliable marketing system, especially through cooperative unions the farmers own themselves. This also is important to ensure that farmers get reasonable prices for their produce.

Communication in the study area

The only tarmac road in the study area is the recently opened one connecting Makuyuni and Ngorongoro Conservation Area (see colour section). The district has gravel roads totalling 514 km, district roads 210 km, regional roads 108 km, and a trunk road 52 km. This implies that it is easily accessible during dry weather but generally poorly to very poorly accessible during rainy seasons, when, and often with great difficulty, only four-wheel-drive vehicles can pass. In addition, inadequate rural road maintenance is also rendering many existing roads unreliable, and along some portions impassable during the rainy seasons. However, road passability is estimated at 62% (URT 2004b). Main road outlets are Makuyuni–Ngorongoro that proceeds to Serengeti up to Shinyanga and Mwanza. In Karatu there is a road connection to Mbulu and Babati Districts.

Opening of the new tarmac road has eased travel to Arusha and Dar es Salaam, and daily buses offer transport services. To the areas where transportation is reliable, there is also a reliable market for agricultural produce; therefore it has encouraged settlement and investment in agricultural production. When good roads are available the cost of transport goes down, and many farmers can gain access to transport.

Karatu town has good telephone services, provided by a number of mobile phones—Vodacom, Celtel and Buzz. At Karatu town, Internet services are available. Personal communication with farmers has shown that accessibility to mobile phones has helped them to get reliable information about inputs and availability of markets (prices and type of community required).

The district's four airstrips are used mainly by tourists and large-scale farmers.

Socio-economic context

Gender issues and division of labour

Traditionally women and youth had limited access to and control of land (Douwe and Kessler 1997), even though they were responsible for most of the agricultural work. However, with market production of beans, horticultural crops, maize, pigeon pea, milk and poultry being commercialized, both men and women are now fully engaged in producing and marketing agricultural produce. Economic forces, relaxed traditional norms, and awareness of women's rights have contributed to women's liberation and engagement in business on almost the same par men. Men normally deal with ox ploughs, tractors and carts, while both men and women transport produce by donkey. Women still carry loads by basket (see colour section).

Many rural households not only depend on crop production but often have additional trading activities. Both men and women are responsible for producing the food crop, and sometimes also the cash crop. Men and boys mostly graze livestock. Women are mostly responsible for collecting water and fuelwood, cooking, and taking care of children, the sick and old.

In some areas of Karatu District, the supply of labour for farming has been declining over time. Many youths find the system used by small-scale farmers tedious and returns low, or they do not have enough land to cultivate and opt to either migrate to towns or remain jobless in the village, loitering and becoming drunkards. Youths want to do away with subsistence farming. Generally, there is enough labour except for some busy periods during the year. The peak demand for labour is during the cropping seasons, that is, during July–September and January–March. Acute labour shortages may be concentrated within a few weeks during critical operations like planting, weeding and harvesting. During such busy periods, medium- and large-scale farmers hire labour, while smallholders ease bottlenecks by working as a group (Meindertsman and Kessler 1997). With the introduction of conservation agriculture technologies, reduced tillage and cover crops have reduced labour on average by 40–75% among hand-hoe farmers using the jab planter together with the ADP knife-roller, and by 60–80% in the draught-animal power (DAP) system when no-till planter was used. (Bishop-Sambrook et al. 2004)

HIV and AIDS

HIV prevalence rate in Karatu is around 20%, which is higher than the national average of 8% (Bishop-Sambrook et al. 2004). Awareness of HIV infection and prevention is high although there is little behavioural change to avoid getting the virus. Some farmers, especially the youth and young adults, have been affected and can no longer participate effectively in fieldwork, while their relatives have had to use scarce resources for medical care of family members suffering from AIDS. A study by Lyimo and Owenya (2002) revealed that AIDS and other diseases have forced families to sell their assets like land, livestock, household utensils and houses. The result has been a reduced amount of household labour, children dropping out of school, reduced purchase of farm inputs, renting out farmland or share cropping, family members resorting to hiring out as casual labour, a decline in livestock and crop production, and a fall in household income. Precious time is used to attend to AIDS sufferers and funerals. Any labour-saving technology in agricultural production would ease the current situation caused by the pandemic.

Labour, cropping calendar and farming systems

Cropping calendar

Traditionally, most land preparation activities, that is slashing, burning of trash, ridging and ploughing, are carried out in December and January; sowing is done in February (table 2). The highest demand for labour is for weeding and occurs in March. Maize, sorghum and wheat are harvested in July and August. Pigeon pea is harvested in October. Beans sown in August are normally harvested in November while those sown in January and February are harvested in April and May. However, with the introduction of conservation agriculture and with the current climatic changes (inadequate or poor distribution of rainfall), the normal cropping calendar has change for individual farmers or localities.

Table 2. Cropping calendar

Activities	J	F	M	A	M	J	J	A	S	O	N	D
Slashing, trash burning, ridging, ploughing	X											X
Sowing	B	X,B						B			B	
Weeding			X									
Harvesting				B	B		X	X		X		

X – maize, sorghum and wheat; B – beans

Intercropping

Intercropping is a common farming practice where maize is intercropped with beans or pigeon pea. Farmers have been doing this to improve soil fertility, intensify crop production and reduce risk by diversifying. Some farmers intercrop maize with pumpkin as a form of crop diversification and intensification (Bishop-Sambrook et al. 2004). Large-scale farmers do not intercrop, rather they rely more on crop rotation. About 60% of the small-scale farmers in Karatu practise intercropping, mainly maize and pigeon pea, where both crops are planted at the same time.

Contour cultivation

Line-level boards and A-frames have been used to demarcate contours while hand hoes have been used to excavate contour trenches and bunds. Napier grass and agroforestry trees have been planted along the contour bunds to stabilize them. However, under heavy storms, contours have failed to stop soil and water erosion effectively as indicators of soil erosion such as splash, rills and inter-rills can be observed between contours.

Agroforestry

Agroforestry has been promoted in the district by several agencies: TAF, MBK, KDC, and others. Agroforestry techniques applied include windbreaks and hedge or strip cropping along contour bunds. Species planted include *Grevillea, Sesbania sesban, Calliandra calothyrsus, Leucaena diversfolia* and *L. leucocephala.* Agroforestry is also practised around homesteads to demarcate boundaries, to serve as woodlots, and for intercropping, relay cropping and sometimes as alley cropping (fig. 3). Nowadays many farmers have realized the importance of planting multipurpose trees and they are doing it themselves.

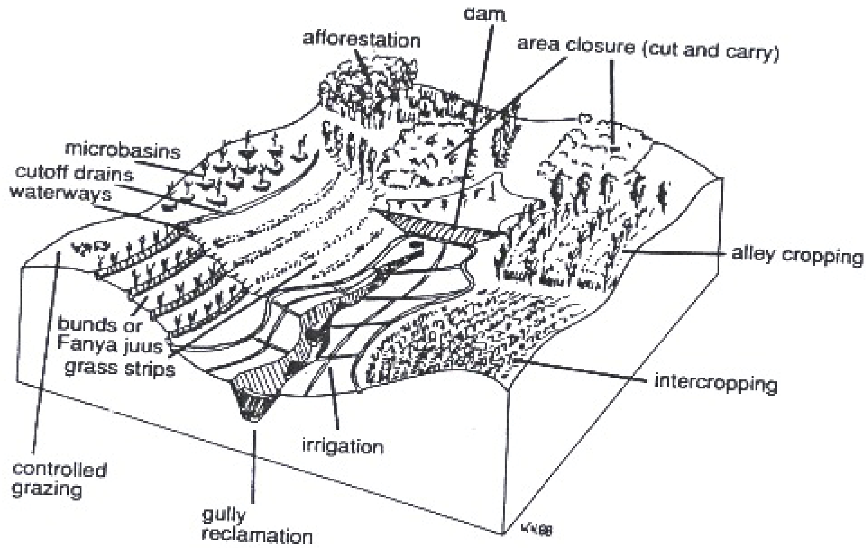

Figure 3. Agroforestry systems practised in the study area.

Crop rotation

Crop rotation is not common due to limited land or lack of knowledge. However, as from 2000, a few farmers have been rotating wheat with lablab and maize. Wheat and barley are grown in pure stands, while for other crops intercropping is the most common practice.

5 Land degradation in Karatu and justification for conservation

Environmental degradation in Karatu District began long ago, during the colonial era (Rohde and Hilhorst 2001). About 80% of Karatu District was considered good for agriculture because it had suitable rainfall and fertile soils (Meindertsman and Kessler 1997). Mechanized and tractor-based agriculture was introduced as early as in the 1960s when settlers[2] cleared more land to allow farming and livestock rearing, which accelerated environmental degradation. By 1976, there were about 370 tractors in Karatu, with their use contributing significantly to degradation problems such as soil compaction. In turn, this resulted in soil erosion, especially on slopes such as in Manyara Basin (COPEC 2003).

2 People come from Mbulu to settle in Karatu because of its agricultural potential.

Erosion is now considered responsible for silting up both Lakes Eyasi and Manyara with drastic impact on both terrestrial and aquatic organisms (COPEC 2003).

Soil erosion and loss of fertility were identified as major environmental constraints in both high and low altitudes of Karatu. On some occasions a lack of well-defined land ownership caused farmers to hesitate to make long-term investments in measures to conserve the environment. In addition, continuous cultivation is a key element in degrading cropped fields resulting in compaction, nutrient mining, structural damage and erosion, as the soil surface is left bare (KDC 2001).

Land pressure on the high-potential agricultural areas in the uplands eventually resulted in increased cultivation of marginal lands (COPEC 2003). Intensive cropping on hill slopes without appropriate soil conservation measures resulted in increased soil erosion and reduced soil moisture capacity, which in turn have led to low agricultural productivity. On-site effects of soil erosion include loss of fertile topsoil and large fluctuations in volume of rivers and springs, leaving behind deformed terrain. Degraded land stores less water, which again makes crops vulnerable to water stress even in a minor drought. Less water stored in upper catchments has a serious negative effect on the smooth supply of water in Lakes Manyara and Eyasi (COPEC 2003).

Offsite effects of soil erosion on the land catena (land top sequence along the slope) cause pollution of water bodies, sedimentation on the farmlands, and physical damage to crops and infrastructure. Currently, there is concern about increased sedimentation in Lake Manyara, which has significantly reduced the lake's volume. Sedimentation is caused by chemical pollution from farming activities at the upper catchment areas. It promotes growth of weeds. Environmental degradation in Lake Manyara National Park may affect wildlife. As this park is one of the most popular tourist sites in Tanzania, there is a real concern that sedimentation and its associated problems may negatively affect the area's tourist industry and the livelihoods of those who depend on it (COPEC 2003).

Farmers still rely on extractive forms of land management, which lead to loss in organic matter, nutrient depletion and soil compaction (pers. comm., assistant DALDO, Karatu). Intensive and regular use of hand hoes for digging, and disc and mouldboard ploughs for preparing land have created a hardpan layer. These hard soil layers hinder rainwater from percolating into the soil, hence less water infiltrates and runoff increases, resulting in surface erosion and gullies. Because the soil's productive capacity has weakened over time as a result of low soil fertility, plough pans and droughts, crop yields have declined. Whereas farmers used to get an average of 15–20 bags[3] of maize per acre[4], currently they are getting less than 5 bags under the same land management (KDC 2001). The low yields have led to severe food insecurity and poor livelihoods as farmers depended on the sale of surplus maize cash. In the past farmers responded to these low yields by opening new fields in more fertile areas but population increase has led to abandoning shifting cultivation and adopting continuous cultivation (Meindertsman and Kessler 1997). In turn, this continuous cultivation led to nutrient mining and severe soil erosion due to the depletion of soil organic matter and hardpan settings.

3 1 bag of maize weighs 100 kg
4 1 acre = 0.405 ha

Lack of information and knowledge about existing technologies that can improve agricultural production and conserve the environment at the same time is an issue. There have been frequent droughts, which have affected crop production, particularly where land is degraded. Strong easterly to south-easterly winds near the end of the dry season contribute significantly to erosion where soils are exposed, particularly those with very fine and light particles (Meindertsman and Kessler 1997; COPEC 2003).

All the problems mentioned above call for comprehensive measures to tackle them together—that is, environmental conservation integrated with agricultural development will lead to sustainable husbandry practices.

6 Institutional initiatives in soil and water conservation

Karatu District Office

Achievements: The District Agriculture and Livestock Development Office (DALDO) some time ago put in place measures to conserve soil and water in selected areas of the Karatu highlands. Under the Department of Land Use and Agromechanization, DALDO has coordinated numerous activities such as tree-planting programmes, agroforestry (improved fallowing, trees around homesteads and along boundaries and contours) and organic farming (URT 2004b). Under the Conservation Tillage Project (CTP), which was a pilot project under the National Livestock Extension Project, NALEP, the following activities were carried out: promotion of a technical package for obligatory construction of contours, draught-animal power ripping, use of farmyard manure, specific row spacing, use of chemical fertilizer and weeding. In 1996, SARI with the support of GTZ started subsoiling services under reduced tillage. Predominantly at ward level, extension agents played an important advisory and technical supporting role in different agricultural and conservation activities. They provided extension services and necessary follow-up to promote use of fertilizers, improved seed, improved breeds of dairy cows, improved milk processing, and use of contours and trees, cover crops and leguminous species. Farmers have continued to apply most of these practices even after the projects involved in their introduction ended.

Gaps and challenges: Extension services at the district level have been limited for a number of reasons including inadequate and irregular government funds together with unreliable transport. In addition, extensionists are generally poorly motivated and often overwhelmed by their professional mandate. This is compounded by the difficulty in accessing rough terrain over large operational areas (a ward may have more than three villages and more than 1500 households).

The agricultural district office had only one computer, which was stolen with all the data; hence following up of some coordination issues and writing reports was made more difficult.

Traditional methods of soil conservation

Achievements: Traditional methods of conserving soil include putting crop residue along contours, using bench terraces, constructing diversion canals, and planting euphorbia trees and sisal around homesteads or plot boundaries. Intercropping maize with beans or pigeon pea, and contour bunds in most coffee estates have a long history dating back to the 1940s. Contour bunds were introduced on wheat farms in the north in the 1940s, but today only a few remain intact (Meindertsman and Kessler 1997). In addition, local bylaws strongly enforced by traditional leaders ensured that all community members adhered to acceptable environmental conservation practices. Bylaws included cultivating along contours in all sloping areas and outlawing uncontrolled tree felling, especially in watershed and sacred areas (traditional areas preserved for prayer or for offering sacrifices). All the bylaws are still applicable but they are not strictly enforced nor is the community aware of them.

Gap and challenges: Many interventions introduced in the area have overlooked indigenous knowledge and practices and this to some extent has led to the failure of many innovations. Low community participation in the whole process of bund construction led to the feeling that this work was the responsibility of the colonial government. Many rural development projects initiated by government to improve environmental conservation undermined building the capacity of the local communities, ignored established participatory bylaws and did not enforce them, and undermined traditional leadership and authority to influence grassroots communities to participate in the project activities.

Project interventions in Karatu with natural resource management components

Regional Integrated Development Programme (1980–1984)

Achievements: The Regional Integrated Development Programme (RIDEP) was a national agricultural project aimed at improving agricultural productivity through soil and water conservation. Project activities included constructing contours, managing natural resources through tree planting, and constructing and maintaining roads. Many trees were planted and bunds constructed. Tree nurseries were established containing trees selected by extension officers. Seedlings were distributed freely to various stakeholders after the onset of rains. Rural roads were constructed and maintained, making access to remote rural areas easier.

Gaps and challenges: The project used a purely top-down approach. Seedlings remained unplanted because farmers were not involved in selecting favoured species and there was no sense of ownership as management was under the project, hence the community paid little attention to the planted trees. Roads were not maintained after the project phased out.

Mazingira Bora Karatu

Achievements: Mazingira Bora Karatu (MBK) literally means 'a better environment in Karatu'. It is a non-governmental organization (NGO), established in the 1980s by a group of 10 people who decided to do something against declining tree populations and rampant soil erosion in Karatu District. In 2001–2003, the World Wide Fund for Nature (WWF) sponsored MBK to facilitate agroforestry, and soil and water conservation practices in the upper catchment areas of rivers that drained into Lake Manyara. Many trees were raised in MBK nurseries and sold to farmers at subsidized prices or sometimes distributed free of charge. Contours were demarcated and constructed in Rhotia and Mbulumbulu. Today, MBK is planting cover crops and is ready to promote conservation agriculture together with other technologies.

Challenges: MBK has faced many challenges in getting funds to implement activities to meet its objectives. Activities could no longer be sustained after WWF phased out and as communities were left without capacity or motivation to carry on with demarcating and constructing contours or with cultivating tree nurseries and planting trees.

There was conflict of interest when 'Frank' in Rhotia, who was a CASARD FFS facilitator, was to help MBK with contour ploughing in 2002 while MBK itself was constructing contours with heavy equipment on hilly slopes. At the same time in a neighbouring field an ongoing IFAD/FAO study was using cover crops and soil cover to conserve soil and suppress weeds. Two institutions (FAO, MBK-WWF) used the same ward officer for competing soil conservation measures.

Karatu Development Association

Achievements: The Karatu Development Association (KDA), registered in 1991 with the aim of alleviating poverty, is one of the oldest NGOs in Karatu District. The organization was sponsored by the Danish Association for International Cooperation (MS-Tanzania) to engage in microfinance, develop agriculture, and improve the environment through extension and demonstration activities, and to provide or make information accessible. The association started demonstration plots on a variety crops—sorghum, paddy and pasture. Many tree seedlings were grown for sale and for free distribution. Demonstrations of how to use the green manure of mucuna and lablab were set in village communal farms and at church and school sites. Farmers appreciated the improvements in soil fertility brought about by the leguminous cover crops.

KDA still exists and is active but now specializes in microfinance activities.

Gap and challenges: Farmers' hopes were raised that they would get a market for their cover crop seeds, but when it turned out that the market was not available they became discouraged and abandoned the innovation. Some of the tree seedlings raised were not the choice of intended community members. No needs assessment or survey had been conducted to find out which trees farmers were interested in. Many trees died or overgrew while in the nursery. Drought threatened the survival of the seedlings. The donor, MS-Tanzania, cut short its sponsorship due to a misunderstanding, so there was no smooth exit of handing over project activities to community members.

Tanzania Association of Foresters

Achievements: The Tanzania Association of Foresters (TAF), formed in 1976, is a professional non-profit NGO, which unites foresters in Tanzania and elsewhere. The association facilitates tree planting and environmental conservation in Karatu District. TAF has been supported financially by Byskogsinsamligen (BSI) of Sweden. The project's achievements include raising about 2.8 million seedlings and creating awareness of the importance of tree planting. Communities became tired of tree planting, however, no longer seeing it as a priority, so TAF switched to agricultural development by providing farmers with improved seed varieties and with training.

Gap and challenges: TAF project interventions in Karatu focused on tree planting but with time the community changed its priorities, and TAF was forced to reorient itself to suit the new interests.

National Livestock Extension Project

Achievements: Administered through the Ministry of Agriculture and sponsored by the World Bank, the National Livestock Extension Project (NALEP-I and NALEP-II) was a government project that aimed to enhance agricultural activities in Karatu District by improving agricultural practices and building the capacity of extensionists (URT 2004b). It operated between 1995 and 2001. Some of the achievements: 15 village agricultural extension officers (VAEOs) were trained on various technologies, 4 VAEOs obtained diplomas in general agriculture, 25 farmers were trained in various skills. It also provided the following support: a vehicle, 2 motorcycles, 20 bicycles, 5 extension kits, 1 computer set, 1 photocopier, 1 soil kit, and furniture. There was also good achievement in disseminating agricultural technologies to farmers and increasing the number of farmers who adopted new skills.

Gap and challenges: The approach was more top down, planned and implemented by government. Little attention was given to sustainable agriculture through maintaining soil productivity. The focus was purely on conventional agriculture. Most of the working instruments provided to extensionists were not durable—for example, the bicycles were of low quality (URT 2004b).

Selian Agricultural Research Institute

Achievements: Selian Agricultural Research Institute (SARI) is one of the main agricultural research institutes in Tanzania. It is a leading player in promoting conservation agriculture in the Northern Zone of Tanzania including Karatu District. SARI officers have been pioneering and spearheading experiments and field testing use of indigenous cover crops such as *Dolichos lablab*, pigeon pea and mucuna. Most of the conservation agriculture-related activities are either directly or indirectly supervised and supported by SARI. SARI is also the main supplier of cover crop seeds in Tanzania and it coordinates subsoiling services in collaboration with TFSC. Almost 30 demonstration plots on smallholder farms were subsoiled free of charge by TFSC (with support from GTZ). Participating farmers were expected to shift to minimum tillage using the chisel plough or ox plough, and to leave crop residue on the field. Cover crop trials were established under TFSC/GTZ sponsorship to examine the effects of lablab and mucuna on soils and yields of maize and pigeon pea. Research undertaken by SARI has been strongly linked to dissemination and training. Farmer field days have been held once a year to raise awareness in the local community and to distribute cover crop seeds. In addition, a large demonstration site was established next to the monthly market ground to stimulate interest among much wider groups of farmers.

Results from field trials conducted between 1999 and 2002 found subsoiled plots typically yielded 4 t/ha whereas plots that had not been subsoiled yielded only 0.75–1 t/ha (Mariki 2003). Cover crops were found to improve yields, soil nutrient status, soil moisture, rainwater capture and retention, total biomass and earthworm numbers. The benefits were often further enhanced if maize stover was left in the fields. According to Bishop-Sambrook et al. (2004), these demonstrable benefits led to about 250 farmers in Karatu, covering 150 ha, adopting the technologies by 2003. By 2003, some farmers had privately continued subsoiling with the help of TFSC.

Gap and challenges: Limited funds and facilities hinder extension work and the introduction of conservation agriculture practices. Currently, they are operating only in some areas of Karatu, Hanang and Babati Districts (Mariki 2003).

Tanzania Farmers Service Centre

Achievements: Tanzania Farmers Services Centre (TFSC) and FSC/Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ) have been promoting conservation agriculture in the belief that one of the major factors causing soil degradation is conventional tillage, that is, excessive ploughing by use of tractor and oxen ploughs or even the hand hoe, which together with removing or burning or grazing crop residues leaves the soil exposed to heavy rainfall, sun and wind. With the assistance GTZ, TFSC intervened to improve agriculture in Karatu District. They offer farmers subsoiling services with a tractor (TZS 60,000 per acre) In collaboration with SARI, TFSC has a demonstration plot with cover crops and minimum and no-tillage trials; it holds workshops and courses on sustainable agriculture, the use of agricultural machinery and efficient crop production; it sells agricultural machinery and spare parts; and it services agricultural machinery (Bishop-Sambrook et al. 2004). However, as a private company, it was more interested in promoting its tractor business and implements, hoping that farmers after seeing the results of higher yields caused by subsoiling would buy its tractors or hire the services. The centre worked in close collaboration with the government, especially SARI, for research purposes and to report achievements (Mariki 2003).

Challenges: Small-scale farmers found centre prices not affordable. TFSC preferred to work on large areas of not less than 50 acres at a time, while many small-scale farmers have an average of 2–4 acres. On the other hand, TFSC faced major challenges when dealing with small-scale farmers whose farms were scattered. Some farmers were dishonest and would not declare the exact acreage of the area to be subsoiled; some did not pay their debts. Machine operators needed close supervision. Thus, TFSC clients are large-scale farmers.

Tanganyika Farmers Association

Achievements: Tanganyika Farmers Association (TFA) has been the main supplier of agricultural inputs with branches throughout country including in Karatu District. The association has been supplying inputs such as seed, fertilizer, pesticides and fungicides, hand tools, draught-animal power equipment and sprayers. TFA is a membership association (fee is TZS 1500); members receive a discount on purchases, have access to credit, share dividends and are provided with free advisory services. It displays agricultural implements and promotes improved and new varieties of crops—for example it has distributed lablab seeds to create awareness.

Challenge: TFA currently faces stiff competition from other agricultural service providers and lacks the incentive to independently promote agricultural innovations because it fears that competitors will 'free-ride' these newly created markets.

Participatory Agricultural Development and Empowerment Project

Achievements: The government of Tanzania with support from the World Bank is implementing a Participatory Agricultural Development and Empowerment Project (PADEP) with the objective of increasing farm income and reducing food insecurity, thereby contributing to a reduction in rural poverty (URT 2004b). This is a five-year project (2003–2008). Project design is based on directly involving rural communities in identifying, preparing, implementing and managing community subprojects. The project is also designed to contribute to strengthening community organizations and district authorities in participatory processes and in improving local decisionmaking. Thirty villages from Karatu District have been selected to participate in PADEP projects. Communities have been trained to identify and prioritize areas that require intervention together with their contributions in implementing the intended activities. Capacity of district to implement this project has been put in place through training staff and providing transport (double-cabin vehicle).

Challenges: Few villages (only one in Karatu) have prioritized the need for conservation agriculture technologies, hence conservation agriculture has not featured much in this national pilot project. This is because most farmers have never heard about conservation agriculture and do not understand its effectiveness in combating a wide range of crop production constraints.

Conservation Agriculture for Sustainable Agriculture and Rural Development Project

Karatu is one of three districts in Tanzania that are part of the FAO-supported and German-funded CASARD project. Karatu was chosen because the donor intended to build on ongoing pilot activities in conservation agriculture. The pilot activities of SARI in collaboration with GTZ/TFSC, ACT, SFI, FAO, IFAD and others convinced the donor to introduce this project with the objective of scaling up conservation agriculture activities. SARI is hosting the project office. Together with the project the farmer field school (FFS) concept was introduced to Karatu. Ten conservation agriculture FFS groups are active and the FFS concept appears to be useful for discussing and assessing various conservation agriculture features at the common FFS field and in the farmers' fields simultaneously. Appendix 1 is a table summarizing institutions and projects in agricultural and environmental conservation.

Third World Congress on Conservation Agriculture—IIIWCCA

The national director of PADEP together with other officials and researchers under the Ministry of Agriculture attended the Third World Congress on Conservation Agriculture (IIIWCCA). Since then there has been a national move to create awareness about conservation agriculture, support the establishment of a national policy supporting it, and build capacity of various key stakeholders in its technologies in the areas of research, extension and marketing. More villages under PADEP now mention conservation agriculture technologies as an important intervention.

Four farmers and one facilitator from Karatu participated in IIIWCCA. They shared experiences with farmers from other parts of the world and took what they learned to other farmers in the villages, hence increased the demand for conservation agriculture inputs and implements.

General observation about all institutions and other stakeholders

There is a general lack of coordination and integration among projects. Stakeholders have not been well identified and coordinated towards a common focus to achieve agricultural, environmental and general development goals in Karatu.

Many new technologies and practices are discontinued after donor support ends because the community is not adequately sensitized and involved. The projects and especially the participation of local communities are usually input driven, and participation stops the moment inputs and grants cease. Beneficiaries are not involved enough to express concerns about their lives and any options that they think may lead to reducing poverty, gaining food security, and conserving the environment. If root causes of key agricultural production constraints are not well identified, a draft participatory community action plan would be helpful, outlining what is to be done, by whom, and when, and the materials required.

The limited adoption of new technologies and practices (including conservation agriculture) to a great extent is a failure of many institutions and projects to build local capacities and to change the innovations to fit into the local customs and physical conditions, and not vice versa. The importance of capacity building in a particular locality needs to be understood, and putting forward appropriate programmes to build that capacity can provide the basis for achieving the desired output.

There were also conflicting technical messages among the development agencies working in the same area; for example, most projects except CASARD promoted ploughing. Farmers tend to prefer ploughing messages because their minds have been turned in that direction.

History of conservation agriculture in Karatu

In the latter part of the 1990s, subsoiling (ripping) was introduced in two districts: Karatu and Babati (Bishop-Sambrook et al. 2004). Key facilitators of conservation agriculture in Karatu include KDA, SARI and TFSC. In 1997, a soil conservation project began in Qurus village. The aim of the project was to encourage the adoption of cover crops such as mucuna, lablab and sunn hemp (*Crotalaria* spp.) through village demonstrations coordinated by KDA. In 1998/99 mucuna performed well during the first year of the project, but it was not adopted. It lacked marketing opportunities as it was a new product without established marketing channels. Furthermore, prolonged drought led to poor germination of seeds and poor establishment of cover crops.

In 1998/2000, SARI and TFSC conducted joint subsoiling activities and cover crop improvement by introducing lablab, which fetches a ready market and is edible. Development of conservation agriculture under SARI and TFSC was in three phases. Phase 1 included subsoiling with tractor (1998) and involved 28 free demonstration plots sponsored by GTZ and implemented by TFSC. The demonstration aimed at motivating farmers to adopt heavy tillage using the chisel plough in the first year, essentially to break up the hardpan and decompact the soil. Phase 2 introduced cover crops in 1999/2000 in 14 trial sites of subsoiled plots. Phase 3 used no-till and direct planting equipment such as jab planters, draught-animal power knife-rollers, no-till planters and sprayers, and tractor-mounted direct-seed drills introduced in 2002.

It was realized that to some extent pigeon pea, which is commonly intercropped with maize, could be used as a cover crop. For many years, farmers had observed the positive impact of pigeon pea on soil fertility, the crop's ability to break hardpan, and its positive impact on moisture retention and weed control, particularly of noxious weeds such as *Digitaria* spp.

7 Conservation agriculture practices

Conservation agriculture aims to conserve natural resources and to make more efficient use of them through integrated management of available soil, water and biological resources. The principles guiding the application of conservation agriculture are:

- Reduce or minimize soil disturbance (that is, soil disturbance in crop production is restricted to the absolute minimum).
- Maintain soil cover of live or dead vegetal matter on the soil surface. This implies that crop residue should not be burned or removed from the fields.
- Rotate crops over several seasons. In addition to minimizing the build up of diseases or pests, crop rotation is essential in sustainable farming as it allows differential use of the soil over time, thereby optimizing plant nutrient use through synergy between different crop types. Alternating shallow-rooting crops with deep-rooting ones is also an important feature in deciding crops in a rotation.

Soil cover

The source of soil cover for conventional farming has been crop residue that after having been chopped for animal fodder is returned to the fields. Managing permanent soil cover is still a problem in annual crop fields but in coffee plantations it has been possible. Generally, a large amount of the soil cover is removed for uses such as livestock feeding, fuel and fencing or is simply burned to get rid of it. After being introduced to conservation agriculture, farmers are striving to ensure soil cover. It is a matter of too little biomass, inadequate knowledge of how to establish pasture plots, and persistent conflicts of interest.

In 2000 mucuna and lablab were introduced as cover crops in the case study area. Many farmers prefer lablab because besides being useful in improving soil fertility, the seeds can serve as food and as a cash crop; the leaves can be used as green vegetables, especially during the dry season when it is not easy to get other green vegetables. At least 350 farmers under an FFS group scheme have at least a plot of cover crop, either mucuna or lablab, where more than 60% of the maize fields are intercropped with pigeon peas (see plate section).

After harvesting maize, pigeon pea is left in the field to be harvested later; therefore, it covers the area during the dry season and forms a very good canopy.

Cover crops are managed mechanically by chopping them with slashers; a few people use knife-rollers. Many farmers are hesitant to use chemicals because of the lack of technical know-how and low purchasing power.

In some way soil cover is traditionally practised in the study area but proper management to fit it into the conservation agriculture system is lacking. Farmers interviewed declared that soil under pumpkin cover looks better in terms of soil moisture conservation and weed control than in areas devoid of such cover. Limited knowledge of how to manage soil cover, inadequate rainfall, fast-decomposing leguminous biomass (lablab, mucuna and pigeon pea), free-range grazing, cut-and-carry methods of handling crop leftovers, and lack of enough planting materials (seeds) have limited attainment of permanent soil cover. Details of the corresponding challenges are discussed in section 11.

Generally, crop residue is meant for dry feeding for animals or is left in the field for free grazing after harvesting. Managing soil cover is still a big problem under conservation agriculture systems, as explained in detail in section 11.

Crop rotation under conservation agriculture

Crop rotation under conservation agriculture generally is *Dolichos lablab* or pigeon pea followed by maize and then wheat. Farmers also rotate crops in intercropped fields of maize and pigeon pea or beans with a pure stand of barley or wheat. Farmers are relatively aware of the benefits they get from crop rotation such as improved soil fertility and control of weeds, pests and diseases. However, in areas with relatively high population density (farm size < 2 acres), farmers want to maximize yields and have different crops on the same piece of land; hence intercropping remains the main option. Households have land enough only to grow their staple food (maize), and cannot reduce the area under maize let alone not grow it for any season. Therefore, what is feasible is to intercrop, with maize always being one of the crops. Intercropping is also desired as it allows the farmers to spread the risks (within the same small field) so that if one crop fails the other may produce something.

Implements used

Implements used in conservation agriculture systems include manual hand hoes (TZS 3000), slasher or panga (TZS 2000), animal-drawn implements such as knife-roller (TZS 300,000), draught-animal power direct planter (TZS 120,000), and draught-animal power ripper with option of planter attachment (TZS 150,000). The hand jab planter is meant for planting through crop residues and crop cover with no tillage. See colour section for different animal-drawn and hand conservation agriculture implements.

TFSC has used subsoilers on several farm (28 farmers) but due to the high cost of hiring the equipment (TZS 60,000 or USD 60 per acre) diffusion was slow and in some places it never took place.

Through the CASARD project a number of conservation agriculture implements (knife rollers, no-till planters, jab planters, rippers) were imported from Brazil in 2004 and have been used by farmers in the FFS groups. These conservation agriculture implements have different options to suit different categories of farmers. The jab planter was for hand-hoe users while direct seed planters were for draught-animal users. Institutions promoting these conservation agriculture technologies had intensive demonstration sessions and supplied leaflets as operational manuals.

The jab planter is popular because it is cheap, easy to operate and available locally. The direct seed planter is more complicated to use because of the need to calibrate the seed rate and manage the harnessing. For farmers with small plots the jab planter is the right tool. Nandra is the main supplier of rippers, jab planters, chisel ploughs and ripper planters.

Inability to purchase or hire conservation agriculture implements is one of the significant constraints to adopting conservation agriculture. It affect all types of farmers although in different ways. Some of the implements are not readily available in Karatu District or even in nearby regions.

8 Entry points, driving forces

Entry point for small-scale farmers

In Karatu because of the dry conditions ripping with draught-animal power was applied as a rainwater-harvesting practice. The primary entry point for farmers adopting conservation agriculture was to increase yields with reduced cost of production and reduced amount of labour.

Farmers were ready to start with animal-drawn rippers because they were familiar with the use of ox ploughs and they welcomed any technology that would help them offset the devastation of the rampant drought, which they had experienced for about five consecutive years. They also easily adopted cover crops intercropped with maize because it was compatible with the traditional system of intercropping maize with pigeon pea, which saw them through the long dry season. The value of the drought-tolerant cover crops, which provided both food and cash, influenced many farmers to pick up the innovation.

Escalating soil infertility, low purchasing power and the ever-increasing price of inorganic fertilizers prompted farmers to practise rotation of wheat and *Dolichos lablab*.

Farmers adopted selected conservation agriculture implements, such as the ripper and the direct seed planter, because they saved labour and reduced the drudgery experienced in many hand-hoe operations. Failure to have time for critical operations such as land preparation and planting was another driving force. With the current unreliable rainfall farmers were required to make use of any raindrop, so early planting to maximize rainfall flash was counted as another entry point. Small-scale farmers with relatively low income adopted the jab planter because of its low cost and ease of operation.

Promoting conservation agriculture in Karatu

Driving forces are issues that compel adoption and sustainability. Success stories of increased yields and profits under conservation agriculture and availability of conservation agriculture inputs created an enabling environment.

Success stories of conservation agriculture technologies from Brazil, the United States, Zimbabwe and other areas were another driving force. Large areas of arable land in southern Brazil suffered such severe erosion that the very livelihood of the farmers was endangered. Initial efforts to contain the damage by constructing terracing were not effective (FAO 2001). Scientists confirmed that erosion resulted from the way land between terrace banks was managed.

Mkoga et al. (2001) observed an overall 60% decrease in labour required when farmers switched from the mouldboard plough to shallow ripping in the maize–draught-animal power farming system in the southern highlands of Tanzania. Various agricultural scientists and extensionists have been keen to follow up and try out some of the reported conservation agriculture technologies and practices.

In January 2000 two no-tillage experts from Brazil, Fatima Ribeiro and Ademir Calegari, together with two FAO officers, Jose Benites and Josef Kienzle, visited Karatu District to introduce the Brazil no-tillage system and to interact directly with farmers, researches and policymakers. They brought along the first Brazilian-made no-tillage equipment to Tanzania—three jab planters and one no-tillage seeder for animal traction. This visit created much interest in conservation agriculture among SARI, other research institutes and the Ministry of Agriculture.

Another driving force has been through individuals. Mr Mariki, senior agricultural research officer from SARI who has made many conservation agriculture study visits and attended workshops in Brazil (2001), Spain (2001) and Zimbabwe (1998), has pioneered a lot of conservation agriculture technologies and practices in Karatu. He has been able to connect experiences from different areas and witness to different stakeholders about the effectiveness of conservation agriculture as a labour-saving technology that improves soil fertility, controls soil erosion, and so on. Success stories he has told indicate that unlike many other soil and water conservation practices, conservation agriculture has been proven to have direct links with high yields, labour reduction, relatively low cost of crop production, and sustainable production under adverse weather conditions.

A study on the effect of **reduced tillage practices** in combination with the introduction of soil cover and cover crops on the effect on labour demand and the suitability of these technologies for vulnerable households was conducted from October 2002 to July 2003 in Karatu. The study was funded by IFAD and executed by FAO Rome in close collaboration with SARI and with one Brazilian no-tillage expert as a study team member. The study results have further strengthened the data pool and provided evidence that conservation agriculture techniques have potential for saving labour and resources (see Bishop-Sombrook et al. 2004).

Political will—policies and bylaws supporting conservation agriculture—can act as a driving force. There are national polices and local government bylaws that address environmental issues. Currently there is no national policy specifically addressing conservation agriculture. What is required is policy on natural resource management and sustainable land management (SLM); then conservation agriculture can be mentioned as a way to achieve SLM. There are bylaws against roaming animals, free-range grazing and uncontrolled wildfires, which, although not established to support conservation agriculture, can do so. Most laws and policies that can and have supported conservation agriculture are indirect, like this one on animal roaming. Communities can propose bylaws they think are useful in protecting their environment. However, there is a need to enforce environmental bylaws. Deliberate efforts are required to foster community ownership of them.

Experience shows that if the bylaws are breached, a fine of about TZS 5000 (USD 5) is payable. If the offender fails to pay the fine, the village extension officer assesses the amount of damage. If the offender refuses to make this payment, the case is forwarded to the police and on to a court of law, and the offender can be sent to jail. The rationale for infringement may be that the amount of the fine is less than the value of one animal in the flock or herd; hence it is better to let the animals feed and pay the fine than lose the whole flock or herd to hunger (Bishop-Sambrook et al. 2004). This implies that some bylaws are too weak to support conservation agriculture in some areas, because uncontrolled grazing would adversely affect people trying to practise its technologies. The government is encouraging village communities to establish and enforce bylaws that will conserve and protect the environment. Under village government leadership, there is an environmental committee, which is intended to deal with all environmental issues of the village. However, the committees lack motivation and capacity to implement their obligation.

Land tenure is another hindering or driving force in conservation agriculture adoption. When population density was low, land was abundant and everyone could have access to as much land as they could cultivate. Under the traditional system of inheritance in the Iraqw tribe, the entire farm was handed over to the youngest son. Other children would be assisted in clearing new land for agricultural activities. But this habit has stopped due to land scarcity, and farms are subdivided. With the advent of Ujamaa (villagization) in 1974 village governments took on the function of allocating land. The amount given per household depends on the availability of land in each district, but on average, it ranges from 1.2 to 2.5 hectares (3–6 acres) per household. Since 1974, most people (80%) obtain their land through this formal system, although a portion still inherit it. The law permits women to own land but many are not aware of their rights. Land that has been allocated to a man remains with his wife and children on his death. Due to land scarcity farmers who feel that they do not have enough land tend to hire from neighbours with big areas or from very poor farmers who have failed to farm. The rental cost is about TZS 25,000 per acre per year. If the hired land is improved, two things may happen. The owner will want the use of it back or will raise the rent. Improving hired land by putting in contours and planting trees means that the renter wants to take the land, forcing a change in ownership because of the investment incurred; so automatically the contract will cease.

Government policies supporting conservation agriculture adoption: The National Environmental Management Council (NEMC) strongly advocates an environmental impact assessment in various projects including agricultural ones. The reason is to establish how to mitigate any negative external impacts. Conservation agriculture has the opportunity to be taken as one of the main technologies and practices that can reduce environmental degradation in arable lands. Current regulations, however, have done nothing with respect to conservation agriculture.

Compatibility of introduced conservation agriculture with other technologies: Many institutions promoting conservation agriculture technologies and practices in the study area have recognized the importance of indigenous knowledge, particularly in relation to the traditional use of cover crops such as pigeon pea and pumpkin. Some components of conservation agriculture such as crop rotation are familiar; the use of lablab has been likened to improved fallowing, which farmers used to practise aa part of agroforestry. Conservation agriculture worked together with other existing soil and water conservation measures such as contour cultivation and agroforestry technologies, which were measures taken towards soil conservation. While contours planted with multipurpose trees and Napier grass failed to control soil erosion in the alley (area between the contours), conservation agriculture technologies and practices have ensured full control of soil erosion and in addition have improved soil fertility and water conservation, which link directly with increased crop yields. Conservation agriculture technologies and practices are compatible with indigenous knowledge used in saving labour such as minimum tillage and application of herbicides.

Conservation agriculture pathway

'Conservation agriculture pathway' refers to a process of adoption reflecting the key decisions and practices (benchmarks) that were made in the process of adoption. This embraces both the technical options and practices and the promotion of the methods.

Pathways of cover crops: Although different conservation agriculture practices such as subsoiling and cover crops were introduced at the same time in Karatu, mainly cover crop practices were adopted. The main pathway in Karatu was the use of indigenous (traditional) knowledge (cover crop and crop rotation). The use of pigeon pea as a cover crop had been practised in Karatu for a long time while lablab and mucuna were recent introductions. Again, lablab was preferred to mucuna because lablab is edible (seeds and leaves) and has a ready market. Lablab is normally cooked with maize and banana and is also used instead of beans in many dishes. In Arusha the same recipe is mixed with sour milk to make a special meal ('loshoro'). Lablab and pigeon pea have a ready market within and outside the country. Lablab at the local market in Arusha town can easily fetch a price of TZS 100,000 per 100-kg bag. In the sowing season of 2003/04, lablab was a scarce commodity, selling at over TZS 120,000.

Pathways of conservation agriculture implements: Adopting cover crops means introducing a direct seed planter, that is, the hand jab planter and the animal-drawn direct seed planter. Implements adopted were according to the status of a farmer. For example farmers with small acreage (< 2 acres) opted for jab planters, while those with 2–10 acres preferred the oxen-drawn direct seed planter. This implies that adoption depended mostly on farm size. Larger-scale farmers with a relatively bigger area of over 20 acres are more innovative and are generally greater risk takers than small-scale farmers.

Pathway through groups—farmer field schools: Community members have been trained in conservation agriculture principles through voluntary groups and organized demonstration plots of different conservation agriculture practices vs conventional practices. Ten farmer field school (FFS) groups with 314 members (158 male and 156 female) have been formed in Karatu District. All groups received basic training in conservation agriculture (what it is, its principles, advantages, how to start conservation agriculture, etc). Other related issues taught included awareness of HIV and AIDS and how the pandemic affects agriculture, how to prepare liquid fertilizer, how to strengthen their groups and get access to credit facilities, how to improve their dairy cattle by integrating conservation agriculture and livestock, seed selection, quality and sourcing, establishment of an input stockist system, grain borer and other storage losses and control, microfinance access and management, and farmer organization and empowerment. Basing on their production problems, the groups went through an interactive process of selecting possible conservation agriculture options that could be tried in the group plot. Treatment plots under CASARD included

maize + lablab; no ripping
maize + lablab + ripping
maize + pigeon pea; no ripping
maize + pigeon pea + ripping
farmer practice

All FFS groups meet once a week, working on the ecosystem Agroecological System Analysis (AESA), which is an integral part of FFS methodology. The project provides legume cover crop seed, which has been planted in farmers' own plots (FFS group members). In addition, each member household in Karatu, that is, 10 FFS groups x 35 members and non-members, received 0.5 kg lablab or pigeon pea seed. It is reported that many of the households had to acquire more seed from the open market to meet their requirements. The seed was provided at no cost to the farmers. However, all households that got the seed are expected to 'pass on' the exact amount of seed received, that is, 0.5 kg to a next farmer, ensuring more access to the seed and more application of conservation agriculture—soil cover and crop rotation.

Members of FFS groups have benefited from capacity-building interventions conducted through agricultural implements and inputs support, intensive training and set forums for group discussions. Although the CASARD project is in its first year of implementation, participating farmers have increased their understanding of the importance of conservation agriculture technologies and practice. In local institutional capacity building, farmers' abilities in group organization are strengthened to facilitate mutual learning and the sharing of information and experience. One of the greatest achievements is the increased morale of different categories of farmers, who engage actively in mobilizing locally available resources and use their own initiative to bring about changes in crop production. Working in groups has helped through sharing experiences and resources and has fostered solidarity, in so much as farmers are beginning to speak with one voice in relation to hindrances in crop production such as unavailability of inputs and capital, the need to form credit and saving societies, and the need for marketing mechanisms. Farmers comprehend the soil-related problems that can lead to stable sustainable crop production even under adverse weather conditions. Group members can explain clearly what they have been doing and the significant changes they have observed in each treatment. The FFS approach has provided an environment conducive to rapid dissemination and adoption of new conservation agriculture-related agricultural technologies and practices.

Pathways through demonstration plots: Depending on the individual household, results from the 28 free demonstration plots conducted jointly by GTZ/TFSC and SARI that were aimed at motivating farmers to adopt the chisel plough were up or down. Alfred, a pioneer farmer, continued with the conservation agriculture practices and modified them to suit his environment and economic purchasing power. Out of 15 acres of land, he subsoiled 3 acres in 2001 but he did not continue with the practice on other plots because it was too expensive for him as an individual to order the service from Arusha, 120 km away. He continued producing cover crops and become a supplier of lablab seeds, sharing his knowledge with other farmers.

Individuals: Alfred is a middle-scale farmer with about 15 acres. He owns a tractor and plough-drawn implements such as a ripper, direct-seed planter, and knife-roller, all acquired through a project, and hand hoes. Alfred said, 'It is difficult to attain permanent cover crops; however, I am on trials. I have observed that finger millet planted in early January tends to have much biomass, hence it covers the soil well, and when harvested in July or August it can stay covering the soil up to the short rains of October or November. Finger millet has more solid biomass than *Dolichos lablab*, which tends to decompose easily just after harvest.'

So suitability of cover crop or crop for permanent soil cover depends on an individual's choice. It is based on experience and access to planting materials, direct economic benefits (cash), food security (edible), usefulness as fodder, rainfall amount and distribution.

Alfred's neighbour Cornel has been copying Alfred. Mrs Cornel said

> *We knew how some of Alfred's plots were degraded so we were surprised to see them back in high production. He explained the secret behind was planting lablab in rotation with wheat. He gave us seeds and we tried and it worked. In the area where we used to get two bags we got eight. However, lack of a special implement for planting wheat through the biomass forced us to plough it under.*

Alfred has now converted 50% of his farm to conservation agriculture.

Another farmer with four acres of lablab also explained the story of copying from fellow farmers. Therefore, the pathway of conservation agriculture in the study area has also been through farmer-to-farmer dissemination of knowledge and practices. Such dissemination has depended on the weather, availability of planting materials, implements, and certain practices the persons who want to copy must undertake. However, inappropriate documentation makes it difficult to tell precisely how many people have adopted the system.

One of the resource-poor farmers, Mama Maria Erro, has been planting beans under conservation agriculture using zero tillage and a jab planter. She started in 2002, being motivated by the government through the Selian Agriculture Research Institute, and has continued to date. She prepares the land by slashing then follows with applying herbicides if they are available. She leaves crop residues as soil cover. She uses the main (long) rain season, January–May, to plant maize, beans, pumpkin, lablab and mucuna. In the short rains, November–January, she plants beans and short-term maize varieties. Because her landholding is small (3/4 of an acre), she has never practised crop rotation.

She has realized several benefits including reduced labour—she depends on her own family labour. The labour used in preparing the land (slashing, collecting trash, burning and starting to plant) has been reduced from nine workdays to two for slashing only. Likewise planting labour has been reduced from four to two workdays.

The few weeds that emerged were removed by uprooting or shallow weeding by panga because the biomass obtained was not enough to provide permanent soil cover and prevent weeds. Observation showed just 10% of the soil was covered.

9 Adaptation, adoption and diffusion

Local and international organizations have been responsible for introducing conservation agriculture technologies in the area. In 2004, FAO through CASARD applied a more organized and coordinated way to introduce the full package of conservation agriculture technologies through farmer field schools.

Adaptation

Conservation agriculture adaptations in Karatu include changes farmers have made in their practices in the standard recommendations to suit their local socio-economic, cultural, technical, agroecological and other local conditions. Generally, no farmer who has tried conservation agriculture innovations has abandoned them completely, but they have modified some technologies to suit their environment. For example, instead of crop rotation farmers have resorted to intercropping because of the shortage of land. Some households lost seeds through poor timing during planting and lack of adequate pest control, but they have sought other seeds to replace the lost ones to continue with the practices. Increase in yield and having lablab as an alternative cash and food crop has been the driving motivation for more farmers to join and continue with conservation agriculture.

Farmers who have adopted conservation agriculture practices have modified their planting times and crop sequence. Instead of relaying cover crops (pigeon pea) with maize, they have decided to intercrop (planting at the same time). When Alfred found that leguminous cover crops tend to decompose rapidly, he opted to use finger millet residue to establish permanent soil cover.

The practices of soil cover and crop rotation have been adopted simultaneously. Lablab in particular has been treated as a cash and food crop, and has been attributed with the ability to improve soil fertility. Hence, a group of about 10 farmers in Rhotia have set programmes to rotate lablab in infertile soils followed with maize, wheat, or finger millet.

Most conservation agriculture practitioners bridge the missing support of inputs such as cover crop seeds and implement by seeking support from fellow farmers. However, the farmer field school approach has brought in much group dynamics, allowing more interaction between farmers and increased sharing of knowledge and resources.

Adoption

Many youths (18–30 years) and some people 40–50 years were ready to adopt conservation agriculture technologies. Youths were eager because they are more business minded. However, lack of capital has prevented many from adopting them. Some youths don't have their own land or they have only a small area obtained from the parents; hence they are not motivated to invest in agriculture.

Large-scale farmers (for example, Msituni Catholic Church Farm) were ready to take up such innovations as subsoiling, and in fact, they were not waiting for external encouragement or even support. With significant financial resources and high levels of literacy, innovative large-scale farmers quickly take advantage of innovations and the opportunities inherent within them. Inherent opportunities include potential reduction in the cost of production, risk reduction through diversification, soil fertility improvement, and maximization of yields.

Diffusion

'Diffusion' is how much and by what process more farmers are adopting and applying conservation agriculture. The main approaches and methodologies used in disseminating and upscaling conservation agriculture practices include forming groups, using innovative farmers, arranging farmer-to-farmer and group-to-group visits and study tours, organizing farmer field schools, managing demonstration plots and field days, and publishing extension field leaflets and posters. On-farm experimentation and trials have been central to local adaptation of conservation agriculture practices.

Combinations of several approaches when well integrated have shown promising results in adoption and diffusion of the innovations.

Generally adoption and diffusion of conservation agriculture technologies and practices have taken place after demonstrations showed their efficiency and effectiveness in combating a wide range of constraints to improved crop production—'seeing is believing'. Their effectiveness in improving rainwater infiltration and conserving moisture, leading to stable higher yields even under inadequate rainfall has motivated many farmers to adopt the technologies and consequently they have become diffused in the community. Demonstrations of conservation agriculture technologies as labour and energy saving have persuaded many farmers to try them, aiding adoption and diffusion.

Most projects attach government extension officers in all activities, expecting that they will continue to disseminate information about the system even after the project phases out. However, in most cases government extension departments are constrained by inadequate staff and working facilities—especially transport and low motivation fostered by low salaries and lack of promotion. Consequently, the diffusion process is often very slow.

Farmers have been invited to internal programme reviews, for example at SARI. Farmers have received farmer visitors from other regions and countries keen to see conservation agriculture activities in Tanzania and to share experiences. Generally, farmers who have achieved outstandingly in adopting and scaling up conservation agriculture innovations have benefited, although sometimes the returns are in kind.

10 Benefits and effects of conservation agriculture adoption in Karatu

Agronomic and environmental aspects in the field

So far farmers have realized high yields per unit area when practising conservation agriculture. Wheat used to yield 3–5 bags per acre; nowadays, reliable harvests commonly average 10 bags per acre (conservation agriculture adopters, pers. comm.). In maize intercropped with pigeon pea, traditional yields were 1–2 bags of pigeon pea and 4–6 bags of maize; farmers are now averaging 3–4 bags of pigeon pea and 15 bags of maize. Proper spacing and use of improved seeds have also contributed to the increased yields (KDC 2001) (table 3).

Farmers have started to reap the benefits of conservation agriculture. Mama Cornel's wheat yields doubled after she rotated with lablab. 'I use to get about 2.5 bags of wheat from my plot. After Alfred shared with me his knowledge and experience in rotating *Dolichos lablab* with wheat, I decided to do the same. In the same area where I used to harvest 2.5 bags, I now harvest 8–9 bags.'

Table 3. Yield increase from Alfred's farm as the result of switching from conventional to conservation agriculture

Crop	Yield before conservation agriculture (bags/acre)	Yields after conservation agriculture (bags/acre)
Maize	7	18
Wheat	3	10
Finger millet	4	9
Beans	2	6

Farmers have explained the way they have increased the yield of beans by zero tillage and application of cover crops. 'On one-third of an acre I planted just 9 kg of beans and harvested 1.5 bags. Other farmers who continued with conventional practices harvested very little,' Mama Elizabeth testified. Farmers described the way they save time, labour and were relieved from drudgery by applying conservation agriculture.

Several farmers have reported reduced costs of production by using conservation agriculture technologies. No tilling and low weed infestations have lowered the cost of production, as narrated above and shown in table 4. However, currently, conservation agriculture has not affected the community significantly. Adoption is still at an initial stage, particularly in terms of the number of individuals who have adopted the technologies and the partial nature of adoption.[5]

For instance, farmer Alfred has achieved some success in permanent soil cover management, hence better weed control and maximum conservation of soil moisture. Conservation agriculture application saved labour (table 4).

Under soil cover the number of weedings required has been reduced from three to one, and the task is eased as only uprooting the weeds is sufficient in some fields. Use of herbicides (mainly Round-Up) has been used in the early stage of 1–3 years of the establishment of cover crops. Generally, after reduced tillage and soil cover are adopted, weed infestation seems to decline; reduced or no tillage also reduces or removes them whereas ploughing merely replants them.

Conservation agriculture fields retain soil moisture longer. Farmers using cover crops have reported a reduction in soil erosion and increased soil fertility.

Table 4. Labour requirement by different activities in conventional and conservation agriculture

Activity	Conventional agriculture		Conservation agriculture	
	Method	Labour required	Method	Labour required
Land prep.	slash, hip, burn, plough	3 persons x 6 days	slash, spread	3 persons x 2–3 days
Seeding	hand hoe	4 persons x 3 days	jab planter	2 persons x 2 days
Weeding	hand hoe	not mentioned but easier	scraping by panga	not mentioned but takes more time

5 Partial nature: adoption and application done on only part of the household's fields; also, adopting some components of the system, for example, only keeping the soil covered and not taking up other conservation agriculture practices.

Socio-economic and process aspects

Workload and division—men and women sharing labour under conservation agriculture practices

By adopting conservation agriculture practices, the workload and the division of labour between men and women have changed. The few farmers who have adopted zero tillage simply wait for planting time as they do not plough. Men, traditionally responsible for land preparation, are no longer occupied by that task, so they have more time to do other development activities. Women and children were responsible for planting. This has changed. Now men also are involved in operating the no-till direct seeders, which takes less time, hence women have more opportunity to do other activities. In many areas, weeding is still done by scratching or uprooting, as the soil cover is not sufficient to suppress weeds.

Employment for small-scale farmers has been well distributed throughout the year; that is, even in dry seasons they can be harvesting cover crops (lablab, pigeon pea, mucuna) used to suppress weeds. Labour requirements for peak periods have been reduced or the work distributed to slack periods. For example, the critical need for time and labour in the peak period of land preparation and weeding has been minimized while slack time during dry seasons is used for harvesting cover crop seeds.

Economic benefits to conservation agriculture adaptors

Benefits of conservation agriculture to small-scale farmers are mostly explained agriculture technologies and practices. Comparing time and costs required for weeding in conventional fields with direct planting through cover crops on a small scale in Arusha showed many savings in using conservation agriculture components (Kurtz and Twomlow 2003) (table 5).

Large-scale farmers are more business oriented and are therefore ready to look for ways and means that can generate more profit and ensure that they remain in business, as different from the subsistence orientation of small-scale farmers. Large-scale farms have adequate capacity in terms of finance, personnel and materials. They have assets that they can mortgage to get loans, quite the opposite for small-scale farmers. Economically large-scale farmers have benefited from less use of energy and the fewer operations of conservation agriculture, with no ploughing and weeding, as compared with conventional agriculture. Yield is increased, cost of production is reduced, hence farming profit increases.

Table 5. Time required and weeding costs in conventional fields and with direct planting through cover crops

Conventional agriculture		Conservation agriculture	
Labour: manual	TZS/ha	Labour: chemical	TZS/ha
1st weeding: 16 workdays	8,000	Renting of sprayer	1,000
2nd weeding: 16 workdays	8,000	Round–Up application: 1 workday	5,200
		Collecting water: 0.5 workdays	500
3rd weeding 12 workdays	6,000	Uprooting weeds: 6 workdays	3,000
		Uprooting weeds: 6 workdays	3,000
Total: 44 workdays	22,000	Total: 13.5 workdays	12,700

500 TZS per workdays. TZS 1200 = USD 1

11 Challenges in Karatu

The challenges are drawn from the projects, which have tried to work on conservation agriculture technologies in Karatu so as to be a lesson and a model for new project interventions. The challenges are two: to promote conservation agriculture to farmers and to get them to adopt it. These challenges are so intermingled that it is not possible to separate them entirely.

Project sustainability not ensured in many projects

Project sustainability, through the beneficiary's ownership and capacity building in conservation agriculture technologies, has not been properly observed; consequently many project activities have ceased immediately after donor support phases out. This cessation can be attributed to several factors: failure to observe participation properly or to build community-based expertise, donor withdrawal premature, inadequate government or community support, inadequate marketing of cover crops, etc. Most projects were designed, implemented and analysed by external facilitators, such as researchers, with minimal involvement of farmers; hence they lacked smooth continuity.

Inadequate coordination at the district level

The different conservation agriculture stakeholders in Karatu are not well identified or coordinated towards achieving the set goals through tackling different objectives, such as introducing conservation agriculture technologies, following through to ensure adoption, diffusion and scaling up, assuring proper documentation, including a database of conservation agriculture activities. It is difficult to tell who did what, when and where, and what has been achieved.

Too much focus on individual farmers and lack of proper analysis

Most of the previous efforts focused on individual, innovative farmers, and this to some extent hindered the fast spread of the technology. Except for the farmer field school approach, which has started only recently, community sensitization to create awareness and readiness to participate fully in conservation agriculture technologies was lacking or has been minimal. However, it seems that even the field schools did not properly carry out SWOT (strength, weakness, opportunities and threats) analysis of conservation agriculture technologies as an intervention to improve crop production. This probably explains why inputs, implements and local capacities were not properly considered.

Limited extension staff and knowledge of how conservation agriculture can best fit in different systems

Variations in biophysical and socio-economic or sociocultural contexts have placed a significant burden on conservation agriculture facilitators in terms of keeping abreast of information. Information and knowledge deficits have resulted in less than adequate support from agricultural extensionists. These deficits have been further exacerbated by the knowledge-intensive nature of conservation agriculture, that is, how to use specialized implements, how to approach farmers to change their mindset, how to convince them to switch from conventional farming practices, demonstrating how to manage soil cover, etc. In addition, the number of extension staff in the district is low; many must cover an entire ward rather than a village. Extensionists are adversely affected by few incentives, limited working facilities, and a hostile environment.

Lack of implements in the district

Conservation agriculture implements are not readily available at the district headquarters, and some are too expensive for farmers to buy. Local artisans are not trained in how to make the required conservation agriculture implements. A good number of people who practise crop rotation of wheat, maize and beans have realized that they don't have direct seed implements for wheat; hence they have decided to plough under, and no longer practise conservation agriculture.

Inadequate policy analysis and advocacy of related issues

Few attempts have been made to analyse the policy environment of conservation agriculture or to advocate conservation agriculture technologies in national policy processes regarding agriculture and natural resource management. The district does not have an agricultural resource centre dealing with conservation agriculture technologies, inputs and implements, and it is difficult to depend on services from afar. When inorganic fertilizers were being promoted, there was a national campaign with the government subsidizing fertilizers. Concurrently technical, material, facilities and financial support were readily available from FAO/Global 2000 to facilitate and build capacity at institutional and grassroots levels.

Problems of attaining permanent soil cover and weed control

Weed management, especially in the initial stages of adoption of conservation agriculture, is a major problem. The main reason is that both cover crops and crop residue have other immediate advantages to the farmers and their families. Availability of rainfall, management of the soil cover and time of planting the cover crop affects biomass production. However, farmers prefer the cover crop and soil cover options compared with the use of herbicides—mainly as the cover crops fertilize as well as cover the soil, and herbicides are designed only to kill weeds (Bishop-Sombrook et al. 2004).

Competition for livestock feeds and soil cover

Approximately 90% of Karatu small-scale farmers practise mixed farming. Traditionally, crop leftovers are kept as dry season feed; it is almost impossible to leave crop residues as soil cover while animals are starving.

Weak bylaw establishment and enforcement

Land rights are weak and the poorest farmers reported that it is difficult for them to claim their land rights because the process is cumbersome and the outcome uncertain. Enforcement of existing bylaws is weak; bylaws proposed by the community are long delayed before getting district approval.

Limited access to cover crop planting materials

Many seed stockists sell seeds, mainly of maize, horticultural crops and sunflowers—but not cover crops. This is where the facilitating role of SARI comes strongly into play. The role could go as far as supporting new stockists with the supply of cover crop seeds in the villages where the demand is high.

Low rainfall

As people are shifting from populated potential areas (highlands of Rhotia and Mbulumbulu) to marginal lowlands, establishing cover crops becomes more difficult as with an average annual rainfall of 300 mm, the rains are inadequate.

Limited knowledge in agronomic practices for different cover crops

Many farmers (about 250) were ready to plant multipurpose crops that can also provide food and cash. That means they need to abide by all agronomical practices—timely planting, use of certified seeds, proper spacing, weeding and pest control, proper harvesting and storage. That trend of knowledge is lacking so that farmers growing lablab and pigeon pea have being complaining about poor yields due to poor agronomical practices and postharvest loss due to poor storage.

Conservation agriculture technologies and practice require intensive knowledge and experience, which at present is not available locally. A functioning local network of conservation agriculture stakeholders in the district with good links to the centres such as Arusha is essential to keep knowledge sharing going among farmers.

12 Conclusion

As conservation agriculture is still in its initial stages in the district, no big impact has yet been realized, although the future is bright. The technology has the potential to release small-scale farmers in Karatu from food insecurity, environmental degradation and poverty, especially considering that they form 85% of the population. With the current climatic change of inadequate rainfall and poor distribution, poor soil fertility, and shortage of labour due to AIDS and migration of workers to the towns, conservation agriculture practices become a promising coping strategy for improving agriculture and rural livelihoods.

However, the decision by households to invest in land for higher productivity is based on many factors. Land tenure, size of farm holding, use of farm inputs, availability of agriculture credit, availability and effectiveness of agricultural extension service, farmers' awareness of the available technologies, farmers' ability to afford and apply the technologies and overall agricultural infrastructure all are issues that must be considered in promoting conservation agriculture in terms of an innovation system. The challenges that farmers are facing in adopting conservation agriculture technologies and practices, not just obstacles to adopting and diffusing it, should be met first in one way or another. In addition, farmers believe strongly in what they have being doing; they are hesitant to change to new things unless they see that immediate benefits are attached to the new practices. Conservation agriculture programmes covering different farming systems are needed rather than uncoordinated short-term projects.

Adoption and diffusion rely heavily on the district agricultural and planning offices, as they have the mandate to plan and coordinate all agricultural activities in their area. They need to create awareness in their communities and identify interventions needed in various localized areas; that is, promoters of conservation agriculture should avoid blanket recommendations. An environment of conducive polices and their enforcement, incentives, inputs and subsidies, credit and loans, and marketing can all serve as a good driving force to ensure adoption and up-scaling of conservation agriculture.

All the problems mentioned here call for comprehensive measures that will tackle several issues together. Given that Karatu District is one of the most agriculturally productive and one of the most popular tourist destinations in Tanzania, environmental conservation should be given a higher priority. Environmental conservation integrated with agricultural development activities will lead into sustainable land husbandry practices. New appropriate agricultural and natural resource management technologies and practices together with indigenous knowledge for environmental conservation and agriculture improvements will break the vicious cycle of poverty and environment in many communities and create an avenue for sustainable rural sector development in different localities, such as in different farming systems, or agroecological zones.

13 Recommendations

- Currently many projects and institutions that have been working in agricultural development, including in promoting conservation agriculture, have not attained full participation of stakeholders. Therefore, stakeholders in Karatu should be identified and coordinated towards a common focus in achieving the set objectives of introducing conservation agriculture technologies and gaining their adoption, diffusion and scaling up. Collaboration should be made possible with government bodies (agricultural research, district council and village government), like-minded international and local organizations, small-scale farmer beneficiaries, local artisans and suppliers of inputs and implements. Preferably the district agricultural office should be empowered to coordinate all conservation agriculture activities in their area, with information and experience-sharing forums. This should be mandatory, not optional.

- Districts should have proper documentation (a database) of all conservation agriculture and related natural resource management activities. The database should be well documented, that is, who is doing what, where and for what purpose.
- Project sustainability, achieved through encouraging beneficiaries' project ownership, and capacity building in conservation agriculture should be carefully observed so as to ensure that the project will continue even after donor support is phased out. Holistic approaches and interdisciplinary implementation of activities should be put into place to ensure that farmers are developed in a wide spectrum, both socially and economically.
- Because problems are localized, no single solution can cut across the many geographical and socio-economic conditions in Karatu District. Facilitators should have this in mind and whenever possible use indigenous technologies. Experience, self-motivation and creativity in conservation agriculture practices and community mobilization skills are required of all extensionists dealing with conservation agriculture promotion.
- Community sensitization and awareness creation in conservation agriculture might lead farmers to be ready to participate fully in conservation agriculture technologies and practices in their areas. Beneficiaries should be provoked to express concerns about their lives and any options that they think may lead to poverty reduction, food security and environmental conservation. In SWOT (strength, weakness, opportunities and threats) analysis of conservation agriculture technologies in the area in question, communities should decide if such interventions would help them. They should be encouraged to establish root causes of key agricultural production constraints. Participatory community action plans (CAPs) should be drafted, outlining what is to be done, by whom, and when, and the materials required. Monitoring and evaluation should be undertaken, while a mechanism of feedback will allow all stakeholders to know what is going on. Up-scaling procedures for the introduced innovations should be in place to ensure diffusion of the innovations to the entire community.
- There should be a trusted and reliable contact person or group in the village to facilitate mobilization and implementation of conservation agriculture activities in the absence of NGOs or institutions that are introducing the innovation. This would help to coordinate the community, facilitate project activities, and bridge communication within the community, between local communities and the implementing agency, and from the agency back to the communities.
- Cost-benefit analysis should be conducted on all farm enterprises to ensure optimum decisionmaking with regard to what to produce, and when and how to produce it. It is important to apply conservation agriculture in the wider contexts, whereby different crop types (wheat–barley, maize, banana, onions) can be considered. This will enable farmers to opt for crops that have good returns in terms of yield, low cost of production and a good price at market. Keeping livestock in conservation agriculture technologies should be taken as an opportunity and not a threat; therefore the conservation agriculture

package being introduced should consider crop–livestock integration. These catch words should be considered: locally available resources, intensification, diversification, local interest, and livelihood improvement.

- Policy analysis and advocacy of conservation agriculture technologies should be undertaken to ensure the inclusion of conservation agriculture objectives in national agricultural and environmental policies; whenever possible, each district should have an agricultural resource centre dealing with conservation agriculture technologies, inputs and implements.

Encourage conservation agriculture programmes, not projects

- Whenever possible conservation agriculture packages should give simple highlights to small-scale farmers about marketing their produce—offering only products of high quality, sorting and grading, sending samples to different markets, maximizing yields per unit area, advertising, avoiding farm-gate prices, promoting marketing, working in production groups to maximize economies of scale, advocating favourable changes in agricultural development policy, carrying out cost-benefit analysis to judge which crop to produce, processing, storing and adding value, finding alternative use of the agricultural products, producing in a timely manner to maximize opportunities afforded when there is scarcity, and producing under contract.
- Participatory conservation agriculture bylaws should be established to ensure the enforcement of existing environmental bylaws, which can promote the wide and fast adoption of conservation agriculture technologies. Local authorities should be given more mandate in bylaw enforcement after creating awareness to the communities about what ought to be done.
- Innovation needs to be upscaled by increasing the number of new conservation agriculture practitioners and ensuring full adoption of all conservation agriculture practices—no till, permanent cover and crop rotation.
- Many farmers have realized the importance of applying conservation agriculture technologies in their fields, but the big problem facing them is poverty, which reflects low purchasing power for agricultural inputs and implements. It is important for any project or institution facilitating conservation agriculture technologies to make sure it can link community to credit agents or establish saving and credit societies.
- The community-based approach should be encouraged so that neighbours who will not abide by the principles of conservation agriculture will not jeopardize the achievement of individual households. The area may be subcatchment or subvillage, where land should be set aside for conservation agriculture practices, hoping with time they will spread to other areas.
- Reports, posters and other informational materials on conservation agriculture should be translated into local languages in simple phrases and be available in Swahili, to be used by facilitators and farmers. Currently many conservation agriculture reading materials are available only in English.

- With the introduction of conservation agriculture in the existing former practices of soil and water conservation, it is important to consider the practices that promote rainfall capture in the soil (on-the-spot rainwater harvesting) before considering those that aim to control runoff. In all cases they should be complementary in a sequence, not competing alternatives.
- Communities need more awareness of the importance of observing bylaws and regulations to achieve sustainable development. Capacity of good governance at village and ward level is of great importance in ensuring that bylaws and regulations are enforced.
- Farmers should be facilitated to improve their land husbandry, thus providing a more effective response than efforts to combat soil erosion and fertility improvement alone.

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Appendix 1 Institutes and projects responsible for agricultural and environmental conservation development

Organization	Activities	Methods to promote conservation farming	Links with other organizations
Government			
District Agriculture and Livestock Extension Office (DALDO) Ministry of Agriculture	• Provide extension to promote use of fertilizer, improved seeds, improved breeds of dairy cows, improved milk processing, use of contours and trees, cover crops and leguminous species. • Under conservation Tillage Project (CTP), promote technical package of obligatory construction of contours, DAP ripping, use of chemical fertilizer and weeding	• Under CTP, provide soft loans to farmer group of 20–25 members covering improved maize seed, fertilizer, pesticide and 2 Magoye rippers per group • 0.4 ha to be planted following technical package and loan to be repaid after harvest • Technical assistance and follow-up provided by village extension officers	SARI, TFSC
Selian Agricultural Research Institute (SARI), Arusha	• Research, development and diffusion of subsoiling and no tillage with cover crops • Support from FAO, GTZ, IFAD, TFSC	• On–farm and non-farm trials • Demonstration plots • Training • Field days • Provision of cover crop seeds • Promotion of no-till equipment	TFSC, KDA, extension department
Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) Arusha	• Develop, adapt and disseminate appropriate technologies in agricultural mechanization (mainly ox implements), water supplies, sanitation, low-cost housing, rural transport, alternative energy and postharvest equipment • Responsible for mandatory testing of all agricultural equipment and machinery • Parastatal organization under Ministry of Industry and Commerce	• Produced more than 150 jab planters	
Tanzania Engineering and Manufacturing Design Organization (TEMDO)	• Applied engineering research and development institute • Design and manufacture range of manual and engine-driven postharvest equipment • In process of being privatized but currently under Ministry of Industry and Commerce	• Produced 10 Magoye rippers and subsoiler for SCAPA • Opportunity: make drawings of Brazil type no-till DAP planter for tendering process in Tanzania	SCAPA

Organization	Activities	Methods to promote conservation farming	Links with other organizations
RIDEP (1980–1984)	• Improving agricultural productivity through soil and water conservation, i.e. contour construction • Management of natural resources through tree planting, road construction and maintenance	• Seedlings distributed and extensionists work on contour demarcation and construction	National pilot project implemented 1980– 1984
National Livestock Extension Project (NALEP-I and NALEP-II (1995–2001)	• Improve agricultural practices and build capacity of extensionists - Training VAEO - Supply of transport to extensionists - Supply of stationery	• Capacity of the extension staff was built and staff motivated	World Bank–sponsored project
CASARD Project	• Promotion of conservation agriculture technologies under small-scale farmers	• Use FFS approach	Pilot activities of SARI in collaboration with GTZ/TFSC, ACT, SFI, FAO, IFAD
NGOs			
Karatu Development Association (KDA)	• Promote crops such as lablab, mucuna, white millet • Promote no tillage with cover crops • Other activities: gully control, promotion of animal traction, support to women for dairy goats, microfinance for women and non-farm activities, support for safflower production • Initially funded by Denmark, now self-funded	• Provide seeds (mucuna, lablab) • Field days and training • Oxen training and introduction of no-till implements	SARI
Soil Conservation and Agroforestry Programme, Arusha (SCAPA)	• Conservation tillage: sub-soiling, DAP ripping mulching, cover crops, use of farmyard manure, row spacing and fertilizer • Other activities: contour bunds and fodder grasses, tree spacing and gully rehabilitation, gender, fish farming, bee-keeping horticulture, water-harvesting structures, grazing management, improved stoves • Funded by Swedish International Development Cooperation Agency (Sida) and supported by RELMA	• On-farm demonstration trials in Arusha and Arumeru Districts • Data collection and analysis through field days • Imported DAP rippers from Zambia through TFA • Community development officer organizes farmer groups to use ripper in association with subsoiling, mulching, cover crops and farmyard manute • Study tours to Machakos, Kenya	TFA

Organization	Activities	Methods to promote conservation farming	Links with other organizations
Tanzania Farmers Service Centre (TFSC)	• Tractor subsoiling and ploughing, and combine harvester hire services • Sell agricultural machinery and spare parts • Service agricultural machinery • Support conservation agriculture research activities, training and demonstration trials • Hold workshops and courses on sustainable agriculture, use of agricultural machinery and efficient crop production • Initially supported by GTZ, now self-funded; retain a development mandate	• In collaboration with SARI have a demonstration plot with cover crops, minimum or no tillage • Provide machinery for demonstration trials, seeds and conservation agriculture expert support • Promote tractor subsoiling services to farmers (TZS 60,000 per acre)	SARI
Tanganyika Farmers' Association (TFA)	• Supply inputs: seeds, fertilizer, pesticides, fungicides, hand tools, DAP equipment sprayers • Branches throughout country • Membership fee TZS 15,000: receive discount on purchases, access to credit, share in dividend, free advisory services	• Sell to members (on credit) and non-members • Babati depot also sells DAP rippers made by Nandra Engineering works • Opportunity: display lablab seeds to create and awareness	Manufacturers and suppliers
Nandra Engineering works Ltd, Moshi	• Manufacture DAP rippers, spare parts for rippers and tractors (on request) • Also manufacture maize mills, hullers, grain storage tanks, cookers, water tanks	• Facilitate group purchases on credit • Spare parts for ripper and tractors available directly from workshop or shop in Arusha • Opportunity: manufactures no-till direct planter, jab planter	LAMP Babati (rippers), CTP (rippers)
SEAZ Agricultural Equipment company, Mbeya	• Promote DAP to reduce drudgery and improve livelihoods of smallholder farmers • Manufacturers, importers and distributors of various DAP implements and providers of after-sales services • Produced Mkombozi multipurpose toolbar • Train farmers on use of DAP implements • Consultancy and advisory services	• Reproduced no-till DAP planter from Brazil • Sold more than 500 conservation tillage implements (including a ripper attachment for its Mkombozi multipurpose toolbar)	

Organization	Activities	Methods to promote conservation farming	Links with other organizations
Mazingira Bora Karatu (MBK)	• Agroforestry techniques in soil and water conservation - through demarcating contours - establishing nursery trees - selling tree seedlings	• Many contours constructed and trees established	World Wild Fund for Nature
Tanzania Association of Foresters (TAF)	• Started with tree planting • Crop improvement through supply of improved seeds and credit provision	• Many trees (over 280,000) were planted • Awareness created in farmers on the importance of tree planting	Byskogsinsam-ligen (BSI) of Sweden

Appendix 2 Livelihood characteristics in Kilimatembo, Karatu District

Characteristics	Rich (5% HHs)	Medium wealth (45% HHs)	Poor (50% HHs)
Livelihood activities	• Rent out houses and shops • Formal employment • Traders, middlemen • Sell livestock and milk • Sell crops within and outside village	• Teachers • Run small businesses • Traders, middlemen • Sell livestock and milk • Sell crops within and outside village	• Casual labour • Rent out land • Sell crops in village • No sale of crop residues
Land	• More than 4 ha	• 1.2–4 ha rent out land to rich	• 0.4–1.2 ha; rent out land to medium-wealth and rich HHs when need cash
Crops grown	• Maize, beans, pigeon pea, finger millet, sorghum, sweetpotato, pumpkin, wheat, barley, sunflower, flowers	• Mainly maize and beans • Also sweetpotato, finger millet, pumpkin, pigeon pea	• Mainly maize and beans • Also sweet-potato, finger millet, pumpkin, pigeon pea
Use of external inputs	• Some use herbicides (for wheat), pesticides (for flowers) • Very few use improved wheat seeds	• Mainly use improved maize seeds	• Few buy inputs; use only if given free of charge or participate in research trials or demonstrations
Farm power and implements	• DAP: 70% own • Tractors: 20% own; 80% hire tractors for primary tillage	• Tractors: hire • DAP: 70% own draught animals; 40% own ploughs • HHs without animals hire when need arises	• 100% hand hoe
Livestock	• 20–40 cattle • 10% have dairy cows	• 5–10% cattle (majority local breeds) • 20% have dairy cows	• Chickens • A few local cattle • Most keep cattle (1–5 head) from wealthier HH
Distribution of FHH	• Nil	• 15%	• 85%
Farmers participating in study	• 2 MHH	• 1 MHH	• 1 MHH; 2 FHH

Source: Bishop-Sambrook et al. (2004)

DAP – draught-animal power; HH – household; FHH – female-headed household; MHH – male-headed household

Total number of HH in community = 545; proportion of FHH in community = 30% (and increasing steadily

Appendix 3 Estates in Karatu District

Farm name	Total area (acres)	Arable hilly (acres)	Coffee (acres)	Area in production (acres)	Coffee spacing	Trees in production (no.)
Bendhuw	472	350	110	85	9' x 9'	45,900
Bergfriden	350	NA	280	180	9' x 9'	77,200
Edelweiss	980	NA	447	433	8' x 6')	
					8' x 8')	
					9' x 9')	294,710
Endoroftasec	880	264	18	16	9' x 9'	2,685
Finagro Estate	1442	NA	500	460	9' x 9'	247,020
Height	840	300	240	230	6' x 9')	
					9' x 9')	149,740
Karatu Coffee	770	150	300	250	8' x 9'	149,740
Karatu Luthrn	888	100	7	3	9' x 9')	1080
Kiran	850	50	430	350	9' x 9'	187,950
Kongoni	1208	200	200	175	6' x 9')	
					9' x 9')	112,930
Liborius	1180	NA	180	175	9' x 9'	69,270
Marcelawet	220	120	14	14	9' x 9'	7560
Msituni	1180	770	65	15	9' x 9'	16,110
Ndamakai	1556	320	148	8	9' x 9'	12,890
New Brandon	364	30	160	140	9' x 9'	75,180
Ngila	308	80	118	100	8' x 9')	
					9' x 9')	63,300
Ngorongoro	999	375	140	85	9' x 9'	72,900
Nitin	2336	900	400	360	6' x 9')	
					8' x 9')	244,800
Oce	810	NA	200	280	9' x 9	220,170
Pratima	709	400	240	220	9' x 9'	59,070
Rafiki	999	750	80	75	6' x 9'	40,500
Shah Plantat'n	2168	NA	420	420	5' x 9')	
					7' x 9')	338,800
Shangrila	990	800	240	100	9' x 9')	
					8' x 9')	45,900
Sunil	1198	NA	190	180	9' x 9'	96,660
TEC	940	350	280	450	8' x 9')	
					9' x 9')	24,200
Tingatinga	1198	NA	98	92	9' x 9'	49,400
Vipin (Rivacu)	713	120	120	nil	9' x 9'	nil
Small-scale	34.5	2404.4 ha	6011			

Mbeya District

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Ndabhemeye Mulengera, Elimpaa Kiranga

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Abbreviations

ARI	Agricultural Research Institute
AEZ	agroecological zone
CA	conservation agriculture
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le Développement
FAO	Food and Agriculture Organization of the United Nations
FARM Africa	Food and Agricultural Research Management (FARM) Africa
IIIWCCA	Third World Congress on Conservation Agriculture
MAFS	Ministry of Agriculture and Food Security
NAEP	National Agricultural Extension Project
NGO	non-governmental organization
NORAD	Norwegian Agency for Development Cooperation
PADEP	Participatory Agricultural Development and Empowerment Project
SEAZ	SEAZ Agricultural Equipment Ltd
SFI	Soil Fertility Initiative
SLM	sustainable land management
SOFRAIP	Soil Fertility Recapitilization and Agricultural Intensification Project
SUA	Sokoine University of Agriculture
TARP II	Tanzania Agricultural Research Project Phase II
TCP	Technical Cooperation Project
TZS	Tanzania shilling, valued at TZS 1200 to USD 1
URT	United Republic of Tanzania
USD	United States dollar

Executive summary

A conservation agriculture case study for Wanging'ombe and Mshewe wards was conducted between March and September 2005 to document past and current conservation agriculture experiences and develop improved understanding to be shared during the Third World Congress on conservation agriculture in Nairobi in October 2005.

The recommendations came from consultations with development workers in the districts, including interviews with 67 people in six villages. These findings were confirmed by stakeholders in a workshop held near the end of the study. The sustenance and livelihood of about 85% of the 28,250 people who live in Mshewe of Mbeya District and Wanging'ombe in Njombe District depend on agriculture. Concern is growing over the decline in crop productivity from poor financial access to supplies, unsustainable land use from tilling with the mouldboard plough, low and poorly distributed rainfall, and decreasing farm size. These wards have been fortunate to receive funding and technical help in conservation agriculture and to verify its effectiveness. Major interventions were introduced over the years:

Period	Funding organizations	Interventions
1998–2003	TARP II–MAFS and World Bank	Ridges, tied ridges, ripping
2001	NAEP and World Bank for SOFRAIP	Ripping and herbicide weed control
2001–2003	TARP I–MAFS and World Bank	Cover crops, ripping, jab, direct seeding Amelioration of hardpan Agroforestry, nurseries for tree seeds and shrubs
2001–2002	TARP II, SUA and Norad	Ridges, tied ridges, ripping
2004–2006	FARM Africa	Ripping, cover crops, crop rotations
2004–2006	FAO and MAFS (TCP/URT/3002)	Cover crops, reduced tillage, crop rotations

Also participating in these conservation agriculture trials and promotions were the district councils using village extension officers, researchers from the Agricultural Research Institute (ARI) Uyole, development NGOs and suppliers, particularly SEAZ Agricultural Equipment, the Mbeya implement manufacturer.

Since conservation agriculture was introduced in 1998, 201 households from six villages in Wanging'ombe and Mshewe wards were exposed to the technology and 71, 35%, became adopters. Most, 44, were newcomers, mostly from Mayale village, who started using conservation agriculture in 2004. They probably progressed faster than the others because they had financial support to acquire implements.

Reported conservation agriculture benefits came mainly from reduced tillage with the ox ripper, rather than the complete package involving permanent soil cover and crop rotations. The few farmers who adopted conservation agriculture increased crop yields, saved labour, and stabilized crop yield even through drought. However, the yield increase depended much on fertilizer.

1 Introduction

Over 80% of the people in Tanzania's southern highlands depend on farming. Agriculture leads the economy, accounting for over half the gross domestic product. Recent stagnating or declining farm productivity ends in food insecurity and poverty.

The southern highlands have four administrative regions, Ruvuma, Mbeya, Iringa and Rukwa, cover 245,000 km^2 or 28% of mainland Tanzania and have about 5.82 million people (URT 2001). Altitude ranges from 400 m to 3000 m; annual rainfall varies from 750 mm in the lower altitudes to 2600 mm in the mountains and along Lake Nyasa. The tropical and temperate climates favour livestock and crop production.

Farmland in the southern highlands is severely degraded, mainly from exploitive farming. Anecdotal reports suggest compacted soil and reduced productivity in Ismani in Iringa District can be attributed to poor tilling practice, acidified soil in Songea and Njombe highlands from using inorganic fertilizers improperly, and the Great Ruaha River drying up from deforestation and poor tilling in watersheds, and overgrazing (Taruvinga 1995). Concern is growing that the declining productivity is from unsustainable farming practices. Continuous tillage with the mouldboard ox plough in the sandy Njombe soil has created plough pans and low soil organic matter (Ley et al. 2003). Low and poorly distributed rainfall in both Wanging'ombe and Mshewe wards means crop failures often occur.

Conservation agriculture is an approach that aims to overcome land degradation and other productivity problems. It consists of three soil and crop management principles—no soil turning, maintaining permanent vegetative soil cover, and rotating both cash and cover crops. Conservation agriculture as initiated in Brazil in the 1980s, and now in some other Latin American countries, has reduced production costs, increased yields, increased soil fertility and lowered labour needs. It is a promising alternative for farmers in the southern highlands of Tanzania.

Individual components—mulching, subsoiling and ripping—have been practised in the zone for many generations. Research work encompassing all three conservation agriculture principles was initiated by the Ministry of Agriculture Research Institute (ARI) Uyole in 1999 after a study visit to Brazil by an institute researcher.

Farm trials and promotions introduced in Njombe and Mbarali Districts in 1998 centred on ridging with animal traction, tied ridging and ripping compared with the conventional mouldboard ploughing. No cover crops were considered. Weeds were managed by hand hoeing in ploughed plots, the ridger in ridged plots and contact herbicide in the ripped plots. Cover crops were screened for disease tolerance, establishment, biomass yield and optimal planting time at ARI Uyole.

The Tanzania Agricultural Research Project Phase II and Sokoine University of Agriculture (TARP II SUA) introduced a similar initiative in 2001, which targeted the same soil and water conserving structures but did away with herbicides and did not use cover crops. Coverage was expanded to include new villages: Mayale and Kisilo in Njombe District, Matai and Sandulula in Sumbawanga District and Nkundi in Nkansi District. Farmers in each village were trained in groups of 15 households.

In 2001 the Soil Fertility Initiative (SFI) of the Ministry of Agriculture and Cooperatives introduced the comprehensive conservation agriculture package including cover crops, agroforestry, ameliorating hardpans and using direct seeding implements, jab planter and animal- and tractor-drawn seeders. Coverage by ARI Uyole was expanded to include two new villages in Njombe District, Kisilo and Kanamalenga; two new villages in Mbeya District, Njelenje and Mapogoro; and one additional group in Wanging'ombe village.

The latest project for Mbeya District was TCP/URT/3002, initiated in 2004 and supported by the Ministry of Agriculture and Food Security (MAFS) and the Food and Agriculture Organization of the United Nations (FAO). Its target is to reach 250 farmers in nine villages with the complete package of conservation agriculture technology.

The different communities in Njombe and Mbeya Districts have been exposed to different conservation agriculture components or packages. Benefits have been varied, but they have been worth the problems these pioneers faced. The *Centre de Cooperation Internationale en Recherche Agronomique pour le Développement* (CIRAD), FAO, and MAFS with the Technical Cooperation Project (TCP) decided to consolidate the experiences gained in conservation agriculture packages, methods, effectiveness and challenges to share them during and after the Third World Congress on Conservation Agriculture of October 2005 (IIIWCCA).

This report presents a snapshot of trends, achievements, challenges and indications of the way forward.

2 Case study objectives

The case study aimed to improve understanding about conservation agriculture and document past and current conservation agriculture experiences to be shared during the IIIWCCA.

General objective

The objective was to improve the understanding and document past and current conservation agriculture experiences in the southern highlands of Tanzania. With similar studies in African countries, this study developed inputs, including posters, to be shared during the IIIWCCA.

Specific objectives

- Record southern highlands of Tanzania farmers', extension workers' and local decisionmakers' apprehension, acceptance and uptake of conservation agriculture principles and techniques, and draw lessons for conservation agriculture promotion.
- Conduct field activities and workshops to assist documenting the conservation agriculture case study.
- Produce a case study report.

3 Method

Mbeya was selected as a case study area because it had been involved in researching and promoting conservation tillage and cover crop technology for many years. ARI Uyole in Mbeya is the only MAFS research institute with a complete agricultural engineering research section. The high variation in altitude, 400–3000 m, calls for distinct research and intervention experience in temperate cover crops and farming systems, some with frost.

The Mbeya case study began with forming a team with research scientists from ARI Uyole, the agricultural extension field officer of Wanging'ombe Ward, and an implement manufacturer, SEAZ Agricultural Equipment Ltd.

The study was conducted in six villages: three villages (Wanging'ombe, Kanamalenga and Mayale) of Wanging'ombe Ward, Njombe District, Iringa Region, and three villages (Muvwa, Njelenje and Mapogoro) of Mshewe Ward, Mbeya District, Mbeya Region (figs. 1, 2). Choice of the villages was based on how much they had been exposed to different conservation agriculture packages and if they had promoted them. The team discussed the case study tasks, including work plans and a conservation agriculture framework. It identified institutions in the two wards that offered conservation agriculture services. It developed a work schedule and assigned members duties.

Preceding the field survey, key informant farmers were categorized as those who practised conservation agriculture; those who had the exposure and opportunity to practise but did not; and former practitioners who abandoned it (appendix 1). Other approaches to collect information included focus group discussions with farmer groups, workshops and key informant interviews of extension staff and the implement manufacturer.

Field sites were selected to capture the range of conservation agriculture interventions, such as ripping, cover crops, tied ridges, agroforestry, intercropping and rotating crops. Information was collected through discussions and field observations. Photographs were taken to help illustrate written information. The information was coded and analysed using the SPSS computer software program, synthesized and compiled as a zero draft report.

4 Biophysical, socio-economic and institutional environment

Geography of Wanging'ombe and Mshewe Wards

Wanging'ombe Ward is in the north of Njombe District, Iringa Region, on the main road from Mbeya to Dar es Salaam. Wanging'ombe is 150 km east of Mbeya (fig. 1). The ward lies within the main agroecological zone, AEZ 3, also known as the Mufindi–Kidugala plateau.

Mshewe Ward, comprising Muvwa, Njelenje and Mapogoro in Mbeya District, is 50 km north of Mbeya city along the Mbeya–Mbalizi-Mkwajuni road (fig. 2). The ward, classified as AEZ 4f, is better known as the Songwe Msangano Itumba trough.

Characteristics of both ward are detailed in table 1.

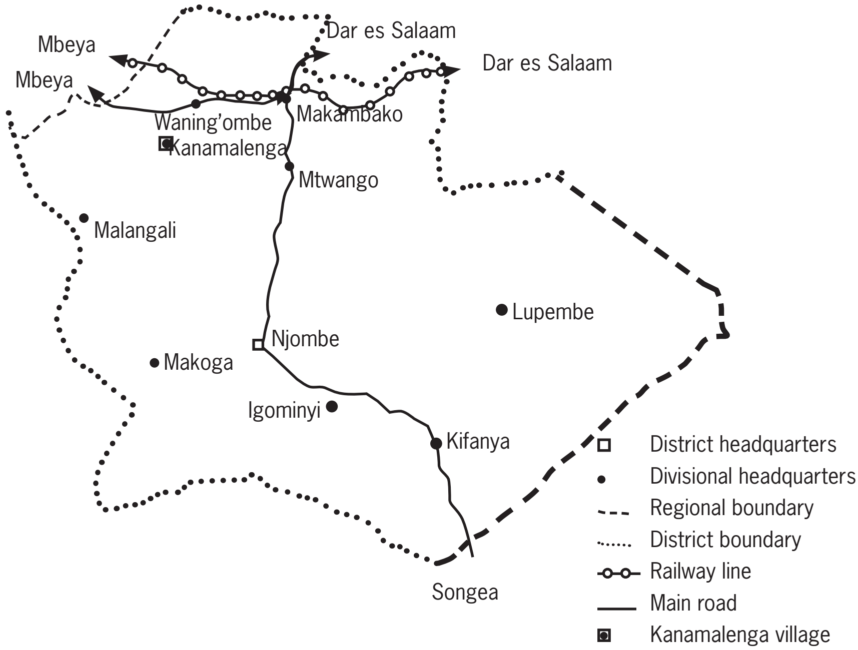

Figure 1. Njombe District with study headquarters of ward in the study.

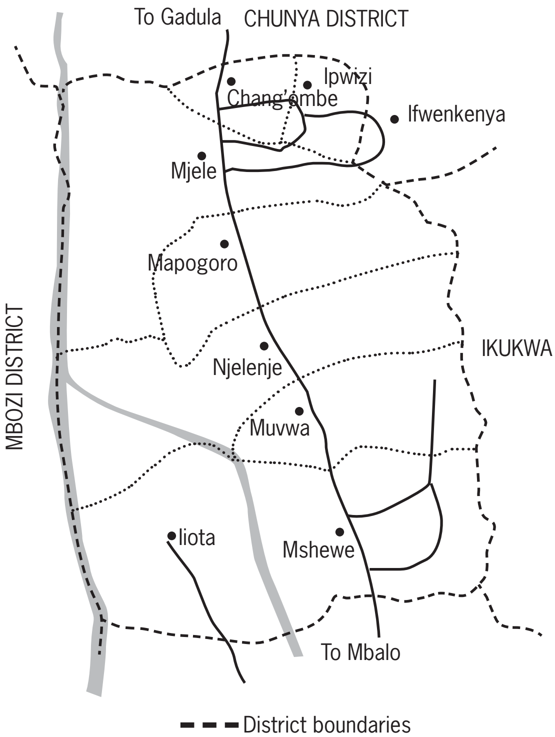

Figure 2. Mbeya District, with Mshewe Ward.

Table 1. Agricultural characteristics of Wanging'ombe and Mshewe Wards

Characteristics	Wanging'ombe	Mshewe
Altitude (m)	1200–1500[a]	1000–1500[a]
Rainfall (annual mm)	600–900[a]	900–1200[a]
Months of rainfall	November–April[a]	November–April[a]
Topography	undulating to rolling[a]	rolling plain with dissected escarpment[a]
Soils	yellow-red sands of shallow depth and hardpan[a]	shallow gravelly ironstone overlying soft weathering rock[a]
Land (ha)	46,325	37,735
Land use	arable, pasture and forest	arable, pasture and forest
Area under crops (ha)	17,580 (37.9%)	6,085 (16.1%)
Farming systems	maize-based, with sunflower, beans and groundnut cattle and goats oxen till more than 80% of the land	maize-based, with sunflower, beans, sweet potato and groundnut cattle and pigs oxen till about 65% of the land
Crop yields (t/ha)	maize: 2.0 beans: 0.13 sunflower: 0.6 groundnut: 0.3	maize: 2.6 beans: 1.0 sunflower: 1.5 sweetpotato: 13
Average area/ household	3.0 ha: maize 1.2, sunflower & cowpea 1.4, groundnut 0.4	1.7 ha: maize 1.0, sunflower 0.5, beans & groundnut 0.1

[a] Mussei et al. 2000 and field data from survey

Health, socio-economic and cultural aspects

The families live in villages of scattered hamlets. The villages have 90 to 597 households, with 651 to 2519 persons (appendix 2). Agriculture is the main economic activity, supported by livestock keeping (table 2).

Table 2. Socio-economics of Wanging'ombe and Mshewe Wards

Characteristics	Wanging'ombe Ward, Njombe District	Mshewe Ward, Mbeya District
Population	18,587	9,863 (5,092 women)
Livelihood	85% depend on agriculture and livestock	90% depend on agriculture and livestock
Ethnic groups	Bena 90%, Hehe 5%, other 5%	Safwa 68%, Malila 17%, Sukuma 8%, Wasongwe 5%, other 2%
Religion	Christian 60%, Moslem 35%, polytheist 5%	Christian 85%, Moslem 10%, polytheist 5%
Education (%)	secondary and higher 7% primary (7 years) 50% incomplete primary & adult education 28% no formal education 15%	secondary and higher 7% primary (7 years) 50% incomplete primary & adult education 28% no formal education 15%
Health services	dispensaries 3	dispensary 1
HIV and AIDS incidence	low, data difficult to verify	low, data difficult to verify

Institutions

Many institutions helped introduce or promote conservation agriculture:

- Directorate of Research and Development, Ministry of Agriculture and Food Security (MAFS)
- ARI Uyole
- World Bank: Participatory Agricultural Development and Empowerment Project (PADEP)
- *Hifadhi ya Mazingira* Project, Iringa
- Irrigation and Technical Services Department, MAFS
- District executive directors, Njombe and Mbeya Districts
- Tanzania Agricultural Research Project Phase II, Sokoine University of Agriculture (TARP II SUA)
- Food and Agriculture Organization of the United Nations (FAO)
- Food and Agricultural Research Management (FARM) Africa

Village committees, which constitute local government, are the most important institutions in harmonizing ordinary, daily lives of rural Tanzanians. Local government leads people to implement local development plans, collects village revenue, resolves social conflicts and enforces bylaws.

Agricultural knowledge is mainly disseminated by agricultural extension agents.

Three agricultural officers serve the 4595 households in the 12 villages of Wanging'ombe Ward, all based at the Wangin'gombe field centre. Mshewe Ward, with 2127 households in 8 villages, is served by four extension officers; three based in specific villages and one in Mbalizi town. The extension officers respond to the official district directives in addition to addressing individual farmer requests and working with external project interventions. They supervise farm conservation agriculture trials and link farmers with researchers and suppliers.

Each village in Wanging'ombe Ward has a primary school. Two secondary schools in Ilembula and Wanging'ombe (within 8 km) are important in providing higher education. Schools are sometimes used as trial sites for new technology.

Wanging'ombe Village also has a dispensary, primary court and monthly livestock market, all important to the ward. The main shopping centre for Wanging'ombe Division is Makambako town, 25 km to the east.

All the Wanging'ombe Ward villages are connected by all-weather roads, which are less than 15 km away from the Tanzania Zambia (TANZAM) highway, connecting Dar es Salaam with Lusaka. The railway (Utiga Station) also serves the ward. All villages enjoy mobile telephone connections and piped water within 400 m from each household. The electricity network is connected to Wanging'ombe village only.

Mshewe Ward has a primary school for each village but no secondary school. The nearest is in Mbalizi town, about 35 km away on a permanent gravel road. Major markets for the crop and livestock products are outside the village, so farmers have to use these roads. Mbalizi town is also the most important centre for the ward; it is the main shopping centre. It has a health centre and several private pharmacies and has the main market for crops and livestock. A monthly livestock market at Mjele, 20 km north of Mshewe, attracts many businesses from outside the district and caters for many needs, including animal-drawn implements and hand tools. The TANZAM highway and a railway station of the Tanzania Zambia railway serves Mbalizi town. Electricity and telephone services are also available.

5 Agricultural enterprises

The livelihood of the people in Wanging'ombe and Mshewe Wards depends almost entirely on crop and livestock production. Over 95% of the labour force is self-employed in agriculture. These farmers eke out a living by using their land, knowledge in selecting crops and livestock, and innovative coping strategies. The affordability of a newly introduced technology or its profitable use depends on these assets.

Crops

The major crops grown in Wanging'ombe Ward are maize, sunflower, cowpea, beans, groundnut, bambara nut, cassava, finger millet, sweetpotato, popcorn and vegetables. All crops are grown for food and cash, except sunflower and popcorn, which are solely for cash.

A background check for Mayale village revealed the area under crop cultivation between 1960 and 1980 tripled from increased use of oxen for farming. However, over the past 20 years, the area under cultivation has remained constant—probably from increasing population density. Conversely, the production of maize and bambara nut has declined, while sorghum, finger millet and tobacco cultivation has ceased. Sunflower, groundnut and cowpea production has gradually increased over the years. Reasons for the increase are better market prices, low demand for external inputs, mainly industrial fertilizers, and increased village sunflower processing coupled with households using the oil and feeding the cake to livestock.

Results of an absolute weighting exercise in Mapogoro village for men showed that 85% of an average household's cash income from the sale of crops, 10% from selling chickens, goats and pigs, and the rest, 5%, from hiring out labour within the village.

Cash income for women in Mapogoro village was 37% from cash crops, 20% from small businesses, 19% from brewing, 13% from sale of small livestock, 6% from hiring out labour and 5% from savings within a group and received periodically (fig. 3).

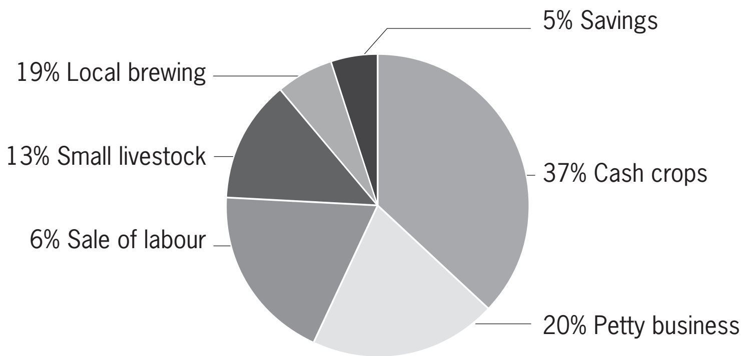

Figure 3. Income sources for women in Mshewe.

Average areas for each household for the different crops are maize 3 ha, sunflower 1.2 ha, cowpea 1.4 ha and groundnut 0.4 ha. Draught animals are the main tilling power source at 85% and hand hoeing is 15% for Wanging'ombe. In Mshewe, draught-animal power is 65%, hand cultivation 30% and tractor 5%. Area with maize intercropped with beans is 35% and sunflower intercropped with cowpea is 50%.

Crop rotation is maize with groundnut or sunflower and back to maize. Beans are often intercropped with maize. The farming calendar starts in November and ends in June. Improved crop varieties are used by no more than 30% of the households and oxen are used to control weeds by less than 5% of the communities. Farmyard manure is greatly valued and used by the Wanging'ombe farmers; its use is lower in Mshewe.

Drought in three out of five years, coupled with low fertility sandy soils and consequent low crop yields were the reason for trying conservation agriculture technology and its adaptations. Timeliness of planting, so vital for better yields in semi-arid lands, could not be done with time-consuming ox ploughing. It could not begin until the first rains. Maize yield had dropped to less than 1 t/ha (Mkoga et al. 2002; ARI 2004, and response to inorganic fertilizer on maize yield was low and unpredictable, partly from low soil moisture (Isaac Kimaro, village extension officer Wanging'ombe Division 1998, pers. comm.).

Because 85% of the land is cultivated by the ox plough, ox-drawn soil moisture conservation with reduced tillage and labour-saving rippers, ridgers and tie-ridgers were introduced for evaluation. Legume cover crops and shrubs (mucuna, lablab, canavalia, tephrosia, pigeon pea and sesbania) were also introduced to improve soil fertility and retain soil moisture.

Livestock

The principal livestock kept by farmers in both Wanging'ombe and Mshewe wards are cattle, donkeys, goats, sheep, poultry and pigs. Cattle are the most important and are owned by about 40% of households. They are used for power, manure, dowry, ceremonial rituals, meat and security during famine.

Households that own cattle find it easier to invest in implements than do those without. Owning cattle enables them to sell an animal to purchase an implement, such as a ripper, and to use draught-animal power. Within households, men decide when to dispose of livestock, except chickens. This gender imbalance hinders introducing draught-animal power for tasks men do not do or do not understand, such as the drudgery in head porterage and hand hoe weeding. Consequently, ox carts for domestic chores, a women's task, or ox weeders for women crops, such as beans and bambara nuts, receive the least investment.

Crop and livestock interaction

The importance of cattle in the farming systems cannot be overemphasized. Manure from cattle is highly valued, although almost always applied without being adequately composted. Oxen provide highly valued power for farm operations. Livestock is herded collectively. About 5–10 households from a single hamlet bring their cattle, sheep, goats and donkeys together and rotate the responsibility of herding them—about two days in two weeks. Details of livestock and ownership are given in table 3.

Table 3. Livestock, livestock ownership and herd size

Livestock	Wanging'ombe		Mshewe		Uses
	Own livestock (%)	Livestock units (mean)	Own livestock (%)	Livestock units (mean)	
Cattle	40	5	35	6	draught, manure, sale, meat
Goats	3	4	5	6	sale, meat, manure
Sheep	1	4	2	4	sale, meat, manure, rituals
Donkeys	1	3	1	4	pack transportation, manure
Pigs	5	3	5	3	sale, meat, manure
Chickens	95	6	85	4	meat, eggs, sale, manure

Source: Survey data

Agropastoralist villages have developed land-use plans that designate settlement, cropping and grazing areas. Grazing is done on communal village lands and, later in the season, on crop residue in individual farmer's fields. Isolated fields in grazing areas would need to be fenced; livestock is not expected to graze in cropped fields. This is normally done with consent of the host farmer. However, permission is not sought when herds from neighbouring villages invade farms, particularly during the drier months of October and November. Mshewe Ward is on a stock route from the Mjele livestock market to Mbalizi town. Cover crops and crop residues on farms on these routes 'get stolen' and are consumed by livestock overnight. Awareness campaigns or enacting bylaws to prevent free-range grazing and bush fires to maintain soil cover should be done by the ward or division and should involve as many stakeholders as possible.

Farmers in both wards have no tradition of conserving livestock feed for the dry season. Conservation agriculture benefits greatly when local, renewable energy sources, including draught power from cattle and donkeys, are used to pull implements. But poorly fed work animals are weak and incapable of working more than three hours at a time at the beginning of the rainy season, when they are needed to produce maximum power.

6 Conservation agriculture work in Mbeya and Njombe

Conservation agriculture technology that included mulch and cover crop soil cover and ripping were introduced in the southern highlands of Tanzania in 1999 after an ARI Uyole researcher, Mr R. Shetto, visited Brazil. Before that, ARI Uyole had extensively used the research station and farms to research and develop soil and water conservation structures, ridges, tied ridges, subsoiling, contour bunds and terraces, with no emphasis on soil cover. The study tour to Brazil was part of the World Bank support to the Tanzania Soil Fertility Initiative that was about to be launched. The visit was to build capacity in the research and advisory services within the zone.

Since 1999, ARI Uyole widened the geographical coverage of conservation agriculture trials and promotions from two to 18 villages. Conservation agriculture has been broadened, involving more stakeholders and addressing as many components of conservation agriculture as possible. Permanent soil cover, rotating crops and direct sowing or reduced tillage with the ripper are now addressed as a package rather than individually (table 4).

Unfortunately, many interventions lasted only three years or less and funding has been limited, usually less than 20% of budgets. It is preferable to know what resources are available when a project is planned to enable stakeholders to choose either a low-funded approach with longer time frames or highly funded effort with shorter-term results. Local district councils need to be involved and commit funds for research and promotion. Links and transitions from one project to another have not been smooth.

Table 4. Conservation agriculture research, development and promotions in Mbeya and Njombe Districts

Duration	Institution	Financier	Technology	Areas	Remarks
1998–2003	ARI Uyole	TARP II – MAFS and World Bank	ridges, tied ridges, ripping (animal traction)	Wanging'ombe and Rujewa villages	structures only, no soil cover
			cover crop screening, cover crop planting time, crop mix	on-station at ARI Uyole	best cover crops determined for agroecological zone and mix
2000–2001	Njombe district extension officer and district executive director	Hifadhi ya Mazingira Iringa	land-use management; agroforestry for soil fertility, firewood, erosion control, improved charcoal stoves	Kanamalenga, Ufwala, Luduga, Banawanu, Mpululu, Igelango, Udonja, Ujange, Korintho	
2001	Mbeya district extension officer and district executive director	NAEP/World Bank for SOFRAIP (PADEP)	ripping and herbicide weed control	Njelenje and Mshewe villages in Mbeya District	
2001–2003	ARI Uyole–Soil Fertility Initiative		cover crops, ripping, jab planter, direct seeding	3 villages in Njombe District: Kisilo, Kanamalenga, Wanging'ombe	complete conservation agriculture package to each farmer
			ameliorating hardpans	3 villages in Mbeya District: Njelenje, Mapogoro, Songwe	
			agroforestry with tree seed and shrub nurseries, improved fallows, relay cropping	Six villages in Njombe District: Luduga, Kanamalenga, Lyadebwe, Wanging'ombe, Ufwala, Mayale	
2001–2002	ARI Uyole and Sokoine University of Agriculture	TARP II SUA–Norad and MAFS	ridges, tied ridges, ripping	Mayale and Kisilo villages, Njombe District	ripping preferred, unsuccessful on soil cover
2004–2006	ARI Uyole, Njombe and Sumbawanga district executive directors, SEAZ, Caritas, DSWT	FARM Africa	ripping, cover crops, crop rotations	2 villages in Njombe District: Mayale, Utiga 2 villages in Sumbawanga: Matai, Mbuza	ox weeding encouraged during transition phase
2004–2006	District extension officer Mbeya, ARI Uyole	FAO and MAFS (TCP/URT/3002)	cover crops, zero or reduced tillage, crop rotations	9 villages in Mbeya District: Mjele, Mapogoro, Njelenje, Muvwa, Mshewe, Itimba, Mwashiwawala, Songwe, Iyawaya	complete conservation agriculture package

The former Mbeya Oxenization Project brought a prototype conservation agriculture ripper and ripper planter to ARI Uyole from Palabana Agricultural Training Institute, Zambia, in 1993. However, farm trials of ripping by ARI Uyole commenced in 1999. Additional rippers were produced by a Mbeya manufacturer—SEAZ Agricultural Equipment Ltd. Importing small batches of implements was cumbersome.

ARI Uyole set zone research and development priorities and chose representative agroecological zones. Wanging'ombe, with the main agroecological zone, AEZ 3, and Mshewe Ward, AEZ 4f, were included in the priorities.

7 Conservation agriculture technology

Conservation agriculture aims to sustain and enhance arable soils. It has three principles: minimal soil disturbance, maintaining permanent vegetative soil cover, and mixing and rotating cash and cover crops.

Conservation agriculture pathway

Ridging, tied ridging and ripping were first introduced at Wanging'ombe village to sustain or increase yields, reduce soil erosion and labour during the frequent years of reduced rainfall.

Introduced conservation agriculture mainly used animal power because it was familiar and the basic equipment, harnesses and carts for manure, were available. Approaches from 1998–2003 used farmer research groups of 10–18 farming households to conduct the trials and promotions. Each farmer was required to have a test plot in his or her own field. Farmers contributed land, oxen and labour, while researchers supplied a set of implements for each group, improved seeds, fertilizers, herbicides and technical support. The village extension officer provided constant supervision and facilitated group organization. Farmer research group members were guided to evaluate and rank the various farm tools. They were encouraged to select techniques for scaling up. Field days for other villagers and outsiders were conducted before harvest.

Project interventions during 2004–2006 chose to use the farmer field schools. These use a common plot and farmers try to analyse conservation agriculture technology, such as planting, weed management, pest control, harvesting and storage. Individual farmers also try to adapt the techniques in their own fields. A village committee of village government officials, farmers and extension officers chose farmers to participate in both the research groups and farmer field schools using criteria developed and endorsed by a village meeting.

Implements used

In both Wanging'ombe and Mshewe, conservation agriculture using animal-powered and hand implements was introduced, since 85% of farmers use oxen and 65% farm by hand. The animal-drawn implements were the ripper, ripper planter and direct seeder; the hand planting tools were the hand hoe and jab planter. The slasher, machete and billhook (*nyengo*) were recommended for managing soil cover. The jab planter and direct seeder were initially imported from the Fitarelli company in Brazil. The Zambia-designed rippers and ripper planters were procured from SEAZ Agricultural Equipment Ltd.

The initial research trial in 1998 compared rainwater capture and storage features of ridges, tied ridges, opening planting furrows with the ripper, and leaving the rest of the land untilled with conventional mouldboard ploughing. Tilling was started two weeks before the expected rainfall. Planting was done before or at the beginning of rainfall. Weeds were managed using the ridger in ridged plots, tie ridger in tied ridged plots, the contact herbicide Gramoxone in ripped plots and the hand hoe in the ploughed plots. These treatments were repeated for the second weeding, except the herbicide was replaced with ox cultivation. For the first three years tied ridges produced the highest yield, followed by ridges, conventional ploughing and with the ripper last. Due to excessive labour needed for ridging and tied ridging, the farmers chose the plough, as evaluated by a pair-ranking matrix.

An obvious weakness in the package was spraying contact herbicide in these farmer-managed trials. The herbicide was usually procured late and inexperienced use resulted in killing the crop. Gramoxone was abandoned for first weeding. The negative experiences included no money to buy the herbicide when needed, dilution leading to low effectiveness, and inexperienced use.

When similar techniques were evaluated in 2001, under the Tanzania Agricultural Research Project Phase II and Sokoine University of Agriculture (TARP II SUA), ridges were replaced with a ripper planter and it was decided to do away with contact herbicides to manage weeds. The 12 households of Wanging'ombe village were dropped, and five new villages, Kisilo and Mayale in Njombe District and Matai, Nkundi and Sandulula in Sumbawanga District, Rukwa Region, were selected. Ridges and tied ridges performed better compared with ripping and ploughing in years of moderate-to-good rainfall, but poorer compared with ripping when rainfall was below moderate. Furthermore, tied ridges needed three times the labour of ripping. Maize yield was consistently superior to that from other treatments (see table 7).

Jab planters and direct seeders were used in the latest conservation agriculture research and development efforts under Soil Fertility Initiative of MAFS introduced in 2001 and also the MAFS- and FAO-supported Technical Cooperation Project of the United Republic of Tanzania (URT) 3002 initiated in 2004. Under the Soil Fertility Initiative, four new villages of Mapogoro and Njelenje in Mbeya District, two new villages of Kanamalenga and Kisilo in Njombe District and one new farmer group were added in Wanging'ombe village. In addition to conservation agriculture, specific themes were cover crops, direct seeding equipment, agroforestry and breaking hardpans. The project for Mbeya District targeted 250 households in nine villages, concentrating on direct seeding and cover crops.

Jab planters worked best in dry seeding in sandy soils or when soil moisture was low. They did not clog. The seeds and fertilizer were planted and germinated almost perfectly. They performed poorly when soils were too wet or under thick soil cover. In a matrix ranking of the planting methods, farmers preferred the ripper.

The direct seeder was second, and rope and hand hoe in ploughed plots was last. The ripper, direct seeder and jab planter had good germination. The ripper was easiest to use. The direct seeder cost the most, but used the least labour. However, there was inadequate soil cover at planting, which favoured the jab planter over the ripper. Farmers who owned oxen considered the jab planter a step backward. Poor farmers without work animals liked the jab planter.

Dry seeding and labour peaks

Introduced conservation agriculture technology greatly improved the timeliness of planting and weeding in the area. Before conservation agriculture, planting followed ploughing, which began with the rains at the end of November and early December. It takes about 32 person-hours per hectare to plant seeds and place fertilizer. The ripper moved up planting from early December to November, before the rains. Idle time became productive and at the same time, the peak demand for labour, for planting and weeding, is spread evenly. The rains come when the seeds are already in the soil. The ripper, which opens furrows without full cultivation, can get the whole farm planted before the rains and has good seed germination.

However, dry planting carries risks. A light first rain, although it will not fully germinate seeds will cause them to swell and rot, requiring replanting. Care is needed to separate seeds from basal fertilizers, if they contain nitrogen or improperly decomposed manure, yet not so far apart to hinder fertilizer use by roots. Contact of the two will scorch the seeds and they will germinate poorly.

Soil cover

In the trial plots cover crops were sown in the maize after the first weeding. Maize residue provided soil cover. Individual farmers could choose a cover crop out of *Dolichos lablab*, mucuna, canavalia, *Crotalaria orchroleuca*, *Lupinus albus* (white lupin) and *Vicia vilosa* (hairy-pod vetch). White lupin and hairy-pod vetch were for the high-altitude Kisilo site (2100 m). Following the maize and cover crop seed harvest, the vegetation had to be protected from free-range livestock, seekers of cut-and-carry feed for their livestock, and bush fires. Lablab, mucuna and vetch are very good livestock feeds. Fences have been effective in Kisilo village, but not in Mshewe and Wanging'ombe.

Awareness campaigns on the detrimental effect of bush fires and the benefits of soil cover have started to bear fruit in some villages, such as Mayale. No livestock have been allowed to graze on a 5-ha farmer field school plot for three years, in spite of the absence of fences. Bush fires have been curbed in a similar way. Village bylaws that restrict bush fires and call for compensation or fines for crop damage are normally enforced. Interpretation of the bylaws is yet to be extended to define residues or soil cover as a 'crop'. The bigger challenge is enforcing the bylaws when cattle herds are in transit and on the run.

No external mulches were brought in from outside the field. Inedible cover crops, such as *Canavalia ensiformis*, have proved valuable during the dry season, especially in the drier Wanging'ombe Division. Live hedges of *Tephrosia vogelii* were preferred in Mshewe, but the shrubs failed to survive in Wanging'ombe.

Farmers were advised to slash the crop residues using the slasher, machete or billhook (*nyengo*) one month before sowing. Cutting them earlier risks fast decomposition and establishing weeds. Dry seeding is recommended, and when this is done, there are no weeds. However, when there is a delay and seeding has to be done when weeds have already germinated, it is recommended to kill them with glyphosate two to five days before planting.

Crop rotation

Crop rotation was not common in the study area, presumably from limited knowledge and the extensive intercropping practised by farmers. However, a few farmers rotated maize intercropped with beans and with sunflower intercropped with cowpeas. Bambara nut was normally grown on the least fertile soil that could no longer support the maize and sunflower rotations.

Indigenous conservation agriculture

Components of conservation agriculture have been practised by farmers in the southern highlands of Tanzania for generations. Planting with minimal soil disturbance has been traditional practice in the drier areas of Iringa, Njombe, Mbeya and Chunya Districts, to save labour and enhance planting timeliness. In the traditional *kukomolea* and *kuberega* systems, a planting stick, dibbler, or a hand hoe would make planting holes in the unploughed soil at the onset of the rains. Hand hoeing or animal-drawn weeding would follow, in addition to mixed cropping with a legume, such as beans, cowpea or lablab. After the grains were harvested, free-range grazing livestock or bush fires would destroy the soil cover. The little crop residue left would be collected and burned a short time before the rains. In the following season, the system started over.

Faidherbia albida, locally known as *mpogoro*, is an indigenous legume tree that grows well in Wanging'ombe. It is recognized for its soil-enriching properties when grown in the field with other crops. It sheds its leaves during the rainy season when crops are in the field and grows new ones in the dry season. Farmers would maintain it if it reseeded in their fields, but they did not know how to raise the seedlings. Farmers learned how to scarify seeds to enhance germination along with nursery management under the agroforestry component of the soil fertility initiative of MAFS. Farmers are now raising their own *Faidherbia albida* seedlings and growing them in their fields.

Mulching and no-tilling in the coffee and banana farming system in the high-rainfall Rungwe District of Mbeya is the only successful indigenous conservation agriculture practice in the zone. Maize, beans, taro and horticultural crops are intercropped with coffee and bananas. Planting holes are made with the hand hoe, and the few weeds that emerge from the banana leaf and chopped old pseudostem soil cover were hand pulled or cut with the hoe. Fertility is maintained by applying kitchen refuse, mulch and manure. However, this farming system has not attracted research. Different interventions are presented in appendix 3.

8 Adapting and diffusing conservation agriculture

Targeted population

All farmers in Wanging'ombe are smallholders cultivating about 2.5 ha (ARI 2004). In Mshewe, 95% of the farmers are smallholders, while the remaining 5% are large-scale coffee farmers with 50–100 ha. The study targeted smallholder farmers who used either hand or animal-drawn implements. The study wanted at least 40% women participants. Albeit the overall low preference accorded to jab planters, women who did not have access to oxen preferred the jab planter to rippers and seeders because they cost less, TZS 30,000 for jab planter compared with TZS 120,000 for a ripper and TZS 400,000 for a seeder.

Introducing conservation agriculture

ARI Uyole clients can ask for preferred technology or seek technology to address a field problem. The annual internal programme review allows farmers, extension agents (including NGOs and projects), suppliers and researchers to interact and review the research and development progress.

All farmers who evaluated conservation agriculture through farmer research groups or farmer field schools were provided with free seeds, fertilizers, herbicides and implements for the evaluation plots. They were also encouraged to borrow the implements to use in their own fields. They could use a plough, jab planter, ripper, direct seeder, hand hoe or ridger. Conservation agriculture implements were introduced to farmers by their preference rather than access.

Only one of the six villages was capable of maintaining most of the soil covered for the whole year against free-roaming livestock. In the other villages, since soil cover was inadequate, weed incidence was high. Weeding was mainly done by hand hoe and ox-drawn weeders, which disturbed the soil. Sown cover crops and maize stover covered the soil until they were eaten by free-range cattle or burned. The fields were therefore generally bare at the end of the dry season—a low entry point for conservation agriculture.

Partners

External partners supporting conservation agriculture in the case study were the World Bank, Hifadhi ya Mazingira Iringa, Norwegian Agency for Development Cooperation (Norad), Food and Agricultural Research Management (FARM) Africa, and the Food and Agriculture Organization of the United Nations (FAO). They provided funding and guidance. Coordination between the partners was missing, leading some to compete for the same farmers, and individual partner strengths could not be exploited. Budgeted funds were not given to the full amount nor for the planned duration. Many well-planned projects were terminated prematurely.

The ARI Uyole researchers worked on testing conservation agriculture technology and setting experiment protocols. They provided basic supplies, implements and technical support. Trial treatments were discussed with village agricultural extension officers for minor adjustments before farmers implemented them. Researchers were also responsible for training farmers and organizing farmer visits and field days. Not all researchers shared a common understanding on the appropriateness of conservation agriculture. There were actually more opponents of conservation agriculture at research stations than outside them. Conservation agriculture interventions were therefore guided by 'dreams' of the leader or closely shared feedback and improvement by a small team of leaders.

District councils were the custodians of these development initiatives on behalf of their people. They could get funding and would allocate them for conservation agriculture, if they were convinced it would benefit farmers and the council. They organized awareness campaigns or enact and implement bylaws for maintaining soil cover. Well-designed bylaws can prevent free-range grazing and bush fires.

Village agricultural extension officers supervised operations of the group as farmers implemented the trials. They enhanced farmer group dynamics and helped form group bylaws involving time management, fines and member rights. Group bylaws were necessary in the new farmer field schools to enhance group efficiency. Without them, time was wasted in waiting for others to come, useless meetings and squabbles. The village extension officers guided the discussions on what members wanted—without interfering in the proceedings. Enacting bylaws was easy, but overseeing their implementation required serious group leaders.

Farmers were obliged to provide work animals for the common demonstration plot at no cost, set aside time for training and make a commitment to train neighbours. Furthermore, each farmer or spouse was required to attend training at a common 0.5–1 ha plot and apply it in his or her field. The farmer could choose among implements, cover crops, crop mixtures and agronomy.

Most groups have kept going beyond the official project lifetime. By retaining the set of test equipment, they continue to use this service, if they have not yet purchased their own. The more advanced farmer groups in Mayale village are registering as savings and credit cooperative societies that will manage the groups' revolving loan fund of TZS 8 million, and keep loaning implements to group members. Group strength was enhanced by the common revenue earned from the farmer field school plot.

Suppliers made improved maize and cover crop seeds, fertilizers and implements available. There are many competing suppliers of seeds and fertilizers, but only one for implements, SEAZ Agricultural Equipment Ltd. The director of SEAZ thought that rippers had been accepted by farmers, creating a reasonable demand, but not for jab planters, knife rollers or direct seeders.

Approaches and methods

The main approaches used to introduce conservation agriculture were 'contact farmers' (1998–2000), farmer research groups (2000–2003), and farmer field schools (2004 to the present).

Contact farmers

In 1996, ARI Uyole used contact farmers to introduce conservation agriculture. These farmers were good agricultural performers, averaging one contact farmer out of 150 farmers. Contact farmers would be individually trained on a test plot within their own fields; neighbours were free to attend. This approach automatically discriminated against youths and poor farmers, who felt shy to attend or would not talk about lower-cost technology. However, the few innovative farmers at an equal income and status were able to use the new concepts for their own farms. Researchers and extension reached few farmers with this approach.

Gender considerations were not spelled out. The male-dominated system made women the natural minority, less than 20%. Women's concerns in the technology were not taken fully into account.

Farmer research groups

Farmer research groups were an improvement over the contact farmer approach. The 10–20 farmers were required to work as a group on deciding what implements, cover crops, and combinations should be tested, daily managing the trial and evaluating the different interventions. Gender issues were built in, with group usually having 30% women. Women's opinions were actively sought.

Training and demonstrations were conducted on individual farmer's fields with other group members attending. All group members would move from one farmer's test plot to another's and discuss the positive and negative plot performance using a checklist.

Farmer field schools

Farmer field schools were the latest approach by the URT, FAO, FARM Africa and ARI Uyole projects. The field school would have 15–20 households with a common interest form a group. Women's participation was required to be no less than 40%. As with the farmer research groups, access (not ownership) to oxen was a discriminatory condition for participation. Emphasis was placed on lessons learned shared with all household members, men, women and youth, and a household must be represented by at least one member in all group sessions.

The field schools had 0.5–1-ha test plots where all the conservation agriculture training was done, step by step, on the work to be accomplished at the time. The group met regularly, usually once a week during the peak season, to do activities planned in the previous week, respond to emergencies, assess how the day's activities could have been done better and plan for the next week. Sessions would last 1–3 hours. The farmer field schools were supervised by the village agricultural extension officer or a farmer trained in field school facilitation.

On farmer field days researchers and extension officers were invited to discuss conservation agriculture concepts, challenges, opportunities and technology. Three to five treatments, covering tilling and planting equipment, cover crops and soil cover would be identified for testing. Paper forms would be designed to record supplies, costs, revenue and facilitate economic analysis.

In the latest FARM Africa project, farmers were trained in participatory monitoring and evaluation so farmers could set their own performance targets and how to attain them, identify interventions that would benefit the community and rally support for them, set up small field school evaluation teams to monitor progress in households and report on deviations for corrective measures.

Promotions

Conservation agriculture evaluation trials are a way to promote the technology. A farmer group should be provided a free set of conservation agriculture implements for the demonstration plot. Implements available to participating farmers' own plots for a small fee provides income for the group. In addition, free improved seeds and fertilizers for the demonstration plots should be provided for the first year. The farmer group was expected to generate revenue from the first harvest to buy supplies for the second and subsequent years.

Field days, normally conducted once in a year at crop maturity when treatment differences are more visually pronounced, are a public affair involving local administrators and neighbouring villages.

9 Conservation agriculture adoption

Adoption rates

Since conservation agriculture was introduced in 1998, 201 households from six villages in Wanging'ombe and Mshewe were exposed to the technology and 71, 35%, became adopters (table 5). Of the 71 adopters, only 2 were from the 8 pioneers of Wanging'ombe who built soil and water conservation structures in 1998. Most, 44, were newcomers, mostly from Mayale village, who started conservation agriculture in 2004. They probably progressed faster than the others because they could acquire implements through a revolving loan and financially stronger farmer field schools that also kept the team spirit going. The adopters dropped to about 20% in Mshewe Ward, probably because it had better rainfall and less drought risk.

Ripping or direct seeding was most valued and adopted, followed by soil cover with cover crops and crop residue. Crop rotations were not systematically conducted. Rotating cover crops was not yet understood.

Diffusion of conservation agriculture technology and having farmers adopt it is painfully slow and complex. Farmers take time, sometimes up to one crop season or year, to trust researchers and village extension officers. True evaluation of conservation agriculture commenced only after farmers were convinced the motives were honest and transparent. Even then, information flow within groups was weak with poor group dynamics. The importance of the farmer field school approach cannot be overemphasized.

Reported conservation agriculture benefits came mainly from reduced tillage with the ox ripper rather than the complete package, involving permanent soil cover and crop rotations. The few farmers who adopted conservation agriculture did it because of increased social status attached to using modern implements, increased crop yields, reduced labour and stabilized yields, especially during drought.

able 5. Conservation agriculture interventions and adoption in Mbeya and Njombe Districts

Village	Financier	Conservation agriculture packages	Households (no.)								
			1998	1999	2000	2001	2002	2003	2004	2005	2006
Wanging'ombe	TARPII, MAFS–World Bank	Ridges, tied ridges, ripper vs plough, no cover crop	8								
	TARPII, MAFS SFI–World Bank	Jab planter, direct seeder, ripper, cover crop vs plough				8					
	TARPII, MAFS SFI–World Bank	Ripper, deep-rooted cover crops I and II vs plough				5					
		Agroforestry									
Kanamalenga	TARPII, MAFS SFI–World Bank	Jab planter, direct seeder, ripper, cover crop vs plough				10					
	TARPII, MAFS SFI–World Bank	Ripper, deep-rooted cover crop I and II vs plough				4					
		Agroforestry									
Mayale	TARPII, SUA	Ripper, ripper planter, tied ridges vs plough				17					
	FARM Africa	Ripper, cover crop vs plough							32	32	
Njelenje	TARPII, MAFS–World Bank FAO	Jab planter, direct seeder, ripper, cover crop vs plough				10			25		
Mapogoro	FAO	Jab planter, direct seeder, ripper, cover crop vs plough							25		
Muvwa	FAO	Jab planter, direct seeder, ripper, cover crop vs plough							25		
Total			8	0	0	54	0	0	107	32	201
Adopters (no.)			2			25			44	Wait & see	71
Adopters (%)			25			46			41		35

Crop yields

Nineteen farmers in Wanging'ombe village were introduced to ripping and improved soil cover with mucuna in 2001. Five doubled maize yield and increased sunflower production 360%, compared with conventional mouldboard ploughing (table 6). However, the variables were not only tilling technique and cover crop but also commercial fertilizers. The other 14 farmers did not get similar yields because they could not afford these fertilizers.

Farmers in Mayale village reported that crops and yields were more stable since adopting conservation agriculture technology. They were able to harvest a maize crop from ripped plots in 2001 when rainfall was merely 560 mm and saved substantial labour, 67.2% (table 7). Ripping captured rainwater, along with local storage. Cover crops, especially mucuna, provided mulch to hold moisture and increase crop stability against drought.

Table 6. Mean maize and sunflower yields using ripping and mucuna in Wanging'ombe and Mshewe Wards[a]

		Yield (kg/ha)		
Ward	Crop yield	Conventional cultivation[b]	Conservation agriculture[c]	Increase (%)
Wanging'ombe	maize	1125	2250	100
	sunflower	750	2700	360
Mshewe	maize	1500	2900	93
	sunflower	625	1500	140

Source: Field data

[a] Means of 5 farmer field school members in Wanging'ombe and 8 in Mshewe

[b] Planting behind the plough at the start of the rains followed by two hand hoe weedings

[c] Opening planting furrows with ox-drawn ripper on unploughed fields before or at onset of rains, hand planting seeds, two weedings with ox cultivator

Table 7. Mean maize yield on farmer trial plots at Mayale in 2001 (7 farmers)

Treatment	Field capacity (ha/hr)[a]	Labour (workdays/ha)[b]	Maize grain yield (kg/ha)
Ox ripper	0.0719[a]	31.6[b]	1344[a]
Ox ripper planter	0.0721[a]	29.6[b]	1059[b]
Ox tied ridges	0.0194[b]	102.6[a]	1021[b]
Ox plough	0.0211[b]	96.2[a]	1066[b]
Grand mean	0.0461	65.0	1122
Variation (%)	29	11	22

Source: Mkomwa 2002

[a] hectares worked in one hour by the ox team, two operators and a pair of oxen

[B] labour for planting, opening a furrow, placing seed, fertilizer and covering seed

More labour would be saved if the full ripper and planter attachment were used. It is possible for one person to open up the soil and plant seeds. The ripper planter, TZS 190,000, was not the choice of farmers because it was more expensive than the ripper, TZS 120,000, and seed metering, with ungraded farmer seeds, was uneven.

Planting calendars

Full cultivation, including placing seed and fertilizer, uses 32 person hours per hectare. The ripper, which opens a planting furrow, enables a whole farm to be planted before onset of rains and provides good seed germination. Time and labour savings from ripping are used to increase the area under cultivation, typically by 20–50%. Therefore, household workload for conservation agriculture is not reduced (fig. 4). Labour saved by spreading out the demand for it enables conservation agriculture households to plant and weed without having to spend scarce cash to hire labour.

Weeding calendars

Conservation agriculture technology shortens the weeding calendar and increases timely operations. In conventional cultivation, farmers use hand hoes to weed. Weeding starts about two weeks after planting. Since it takes 20–30 person days to weed one hectare, weeds germinate profusely in the other fields. Subsequently, crop yields drop, drudgery for women and children increases, and school attendance drops. Under conservation agriculture, weeding is done by ox cultivator. Weeding has to be done twice, leaving a two- to three-week interval. A cultivator with a pair of oxen or donkeys can weed one hectare in 7.5–8 hours. Farmers said that the amount of weeds in fields planted with mucuna in the previous year was greatly reduced, making weeding easier.

Changes in soil fertility and erosion

The soil fertility in the study area is typically low and the soil needs fertilizer. However, fertilizer costs have restricted their use. Only 60% of farmers in Wanging'ombe use commercial fertilizers, either at or below the recommended rates of 0 phosphorus and 20 kg nitrogen per hectare. Farmers noted that the ripper opened small furrows without disturbing the soil and left crop residue and cover crops as mulch, which, after decomposing, improves soil fertility.

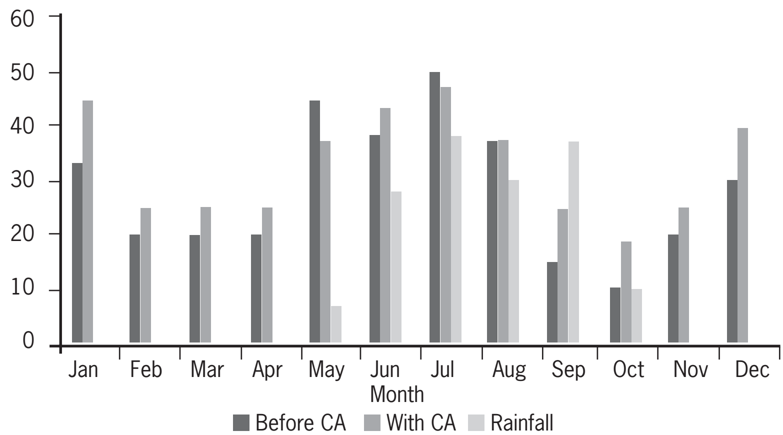

Figure 4. Agricultural workload and rainfall in Wanging'ombe Division (Wanging'ombe field station rainfall data).

Changes in costs and income

The average fertilizer application rate for di-ammonium phosphate at planting and urea for topdressing was 125 kg/ha. Fertilizer was limited to maize and sunflowers, the main staple foods and income source. Soil-enriching cover crops, mucuna, lablab and canavalia, contributed to a significant decrease in fertilizer use. About 26% of the conservation agriculture research farmers reduced fertilizer application by half, from 125 kg/ha to 62.5 kg/ha, saving TZS 58,750, while increasing maize yield from 1125 kg/ha to 2250 kg/ha and sunflower from 750 kg/ha to 2700 kg/ha. Net benefits increased by more than threefold for sunflower and fivefold for maize, mainly by selling surplus maize, increasing sunflower production and reducing cash outlays because farmers did not have to hire labour for weeding (table 8).

Of the 10 farmers who joined the conservation agriculture trials in 1998, only 2 were still practising conservation agriculture in 2002. On the other hand, substituting herbicide with a 'compromise', but more accessible ox cultivator, in neighbouring Mayale village resulted in a group of 29 farmers adopting the technology in only one year. The issue seemed not to be access to cash, but liquidity. Farmers often have cash one to two months after harvest; liquidity drops almost to zero in the other months. Any technology that calls for frequent cash outlays from smallholder farmers two months after harvest is bound to fail.

Cover crop food value and risks

The ripper and cover crops are environmentally friendly compared with the mouldboard plough. The plough consumes labour and accelerates erosion. Inorganic fertilizers impoverish the soil with continuous use.

The safety of some cover crops, particularly canavalia and mucuna, for human food raises a lot of questions from farmers. They want to eat them in the same way as beans or lablab. Since isolated communities consume these traditionally, canavalia for 'coffee' in Wanging'ombe and mucuna for 'coffee' and snack in Songea and Tunduru, there should be no alarm. There is a concern, though, that the six hours of continuous boiling needed to detoxify mucuna for human consumption takes too much firewood. Mucuna seeds were mixed with maize bran in Njelenje village and fed to dairy cattle with a resounding 30% increase in milk production. The safety of the milk is unknown.

Snakes have been a concern in the improved mulch in Songwe prison. Spot application of smelly oils and perfumes and curative stones are carried along for snakebite during knife-rolling, weeding and planting.

Farmer modifications to conservation agriculture

Many farmers modified prescribed conservation agriculture packages:

- A few participating farmers, less than 10%, ploughed their fields before planting. This was done to control weeds when it was not guaranteed they would have oxen during weeding and in households that used traditional arrangements for using oxen. These oxen were shared by

Table 8. Benefits from efficiently using inputs and cover crops (Njelenje village 2004)

Variable	Conventional agric.		Conservation agric.	
	Maize	Sunflower	Maize	Sunflower
1 Grain yield (kg/ha)	1,125	750	2,250	2,700
2 Gross field benefit[a,b] (TZS/ha)	157,500	144,000	315,000	518,400
3 Weeding labour (workdays/ha)	30	25	14	14
4 Weeding labour cost[c,d] (TZS/ha)	5,100	4,250	42,000	42,000
5 Di-ammonium phosphate fertilizer: 125 kg/ha x TZS 540/kg	67,500	—	—	—
– dose halved: 62.5 kg/ha x TZS 540/kg	—	—	33,750	33,750
6 Urea fertilizer: 125 kg/ha x TZS 400/kg	50,000	50,000	—	—
– dose halved: 62.5 kg/ha x TZS 400/kg			25,000	25,000
7 Implement cost[e] (TZS/ha)	400	400	1,200	1,200
Total variable cost (TZS/ha): 4 + 5 + 6 + 7	123,000	54,650	101,950	101,950
Net benefit (TZS/ha): 2–8	34,500	89,350	213,050	416,450

Source: field data

[a] Market price: TZS 150/kg less TZS 6/kg for harvesting, TZS 3/kg for transport and TZS 1/ha for shelling and bagging = TZS 140

[b] Market price: TZS 200/kg less TZS 5/kg for harvesting, TZS 2/kg for transport and TZS 1/ha for shelling and bagging = TZS 192

[c] Ox operator cost at TZS 3000/hour = TZS 3000

[d] Hand hoeing labour hired at TZS 170/ha = TZS 170

[e] Based on annual depreciation and repair costs

extended families of four to eight households. Ploughing was also done for late-planted crops, such as sunflower and groundnut. They need to be planted about three to four weeks after onset of the rains, when weeds have already progressed.

- Reduced soil disturbance was interpreted as weed control by shallow tilling implements or herbicides. Herbicides were unpopular because they cost money when financial reserves were at their lowest. Some farmers used the ripper for the first weeding to prevent soil and residue mulch from covering the small plants during weeding. Many farmers used the ox cultivator for weeding. Some farmers, without a cultivator, used the plough to weed, especially when the field was trashy and weeding was delayed.
- Those who used the direct seeder did not put fertilizer in the hopper to avoid seed burning, in case the rain ceased after the seeds absorbed water from early showers. Then fertilizer was applied after seed germination and when moisture was appropriate.

- Farmers proposed that to improve fertility in the severely depleted soils, mucuna should be left in fallow for two years. They developed a crop rotation system, in addition to mixing and intercropping other crops in the same field.

Conservation agriculture technology effect on workload

The ripper and cover crop significantly enabled farm work to be completed in less time and reduced the arduousness inherent with traditional mouldboard ploughing and hand hoeing. Furthermore, the ripper required fewer people to operate and fewer days (table 7).

Conservation agriculture farmer relationships with neighbours

Introducing and adopting conservation agriculture has improved relationships among farmers within the adopting communities and among neighbours. Those with rippers and cultivators hired the equipment out to other farmers for a modest charge, TZS 12,500/ha. Close neighbours and relatives were trained in how to use the equipment and were helped in carrying out their farm operations. This helped even the low-income households to get access to and benefit from conservation agriculture practice.

Neighbouring and migrating poor farmers who used to hire out to conservation agriculture farmers for weeding lost an income source. The good conservation agriculture practitioners had fewer weeds or managed them with the ox weeders without hiring outside labour. Incidentally, most labourers were women accompanied by children.

Conservation agriculture and female-headed households

The effect of conservation agriculture on female-headed households has not been adequately studied. The status of female heads of household has been very dynamic —with some quickly remarrying.

The conservation agriculture trials sought poor female heads of household as part of the southern highlands' strategy to reach disadvantaged groups. These women did not volunteer to participate in group work. Extra effort was made to get the very few—two out of the eight participants in Kanamalenga. Female-headed households in Kanamalenga village preferred the jab planter to the ripper or the direct seeder. They were able to plant their crops, even when they could not afford to hire oxen for planting. Farmer group members could choose two cover crops out of three, lablab, canavalia and mucuna, for mixed cropping with maize in the seeding and tilling implements. Female heads of household chose lablab because it was edible and not just for soil fertility and cover.

It was not clear what the effect of poor households losing labour income through hiring out to neighbours would be. Hand-hoeing jobs have decreased and will continue to decrease. Medium-income or wealthy female heads of household have not been the most dynamic conservation agriculture adopters. Introduced conservation agriculture technology was based on animal traction, requiring good and confident draught animal handlers—youths; wealthy female household heads were not among them. Their participation was limited to buying draught-animal implements, mainly rippers and ox cultivators, since they expected their sons or neighbouring youths to operate them.

Land tenure system and adopting conservation agriculture

Amost 70% of the land is owned, through inheritance or purchase, by the concerned farmers; the remaining 30% is rented. Around Njelenje village, land rent varied from TZS 15,000/ha in the lowlands to TZS 30,000/ha in the highlands. The study found that farmers were hesitant to plant beans or cover crops in rented plots. Planting beans risked the owner revoking the rent contract to benefit from the residual nutrients. If they planted beans, they strove to rent it the following season to plant maize, if the owner did not revoke the contract. Dry weather, low soil fertility and family land ownership drove farmers to adopt conservation agriculture. Therefore, conservation agriculture encouraged land ownership.

Entry points and pathways

Frequent drought offered a challenge for conservation agriculture in Wanging'ombe Ward. Most land, over 80%, was ploughed by oxen, presenting an opportunity to introduce animal-drawn water-harvesting rippers and subsoilers. Presently, more than 200 households are involved in conservation agriculture in the study area. Most belong to farmer field schools, which build household and group capacity. They attempt to empower farmers to demand, adopt and scale up conservation agriculture and disseminate it.

Government policies affecting conservation agriculture

The government started promoting conservation agriculture through interventions, including two villages by NAEP/SOFRAIP, 12 villages under the Soil Fertility Initiative (2001–2003) and nine villages under the Technical Cooperation Project (2004–2006) (table 4).

Government regulations also influenced conservation agriculture. Free and liberalized supply and produce markets have resulted in more expensive chemical fertilizers and other supplies. At the same time, tractors and animal-drawn implements are tax exempt, making them more affordable. At this early stage, it is difficult to determine what impact, if any, government policies have had on conservation agriculture.

Conservation agriculture equipment was expensive for the poor and very poor households. Although loans for equipment were available, some poor farmers were afraid they might not be able to repay them. Poor farmers were not likely to buy equipment on credit without high government financial support to groups. In this case, government policies negatively affected conservation agriculture adoption. Also, when the government has no control over agricultural product prices and they are lower than supply prices, the adoption of conservation agriculture will be negative. The income expected from crops grown using conservation agriculture equipment will be insufficient to pay off the equipment.

10 Gaps and challenges

Despite the several benefits, conservation agriculture practices in the study area still face challenges, which include policies, knowledge and affordability.

Skills gap

Conservation agriculture was new to most extension staff, farmers, researchers and private agribusiness. As most service providers had inadequate knowledge and skills related to it, they needed training. Furthermore, conservation agriculture projects need to be linked with their results to build an institutional and technical memory of Mbeya.

Affordability

Farmers who used conservation agriculture equipment with research and extension appreciate and liked the benefits. However, few were able to afford the direct seeders and rippers, let alone the herbicides that demanded frequent cash outlays.

Technology spontaneously adopted by farmers

Farmer Michael Mwatukambo of Njelenje village decided to plant a traditional sorghum, which is very tall and has high biomass but low grain yield, to generate more biomass on his badly degraded field. The sorghum, intercropped with mucuna, produced a high volume of slowly decomposing biomass, which covered the soil for the whole year.

Farmers in Mshewe Ward individually tested different indigenous lablab and mucuna to determine establishment, grain yield and insect tolerance. Mucuna seed stockpiles induced a farmer in Njelenje village to experiment with using it as an additive to dairy concentrate. He said he realized a 30% increase in milk and attributed this to mucuna.

Land tenure

Scarce land holdings coupled with inadequate entitlement caused few farmers to allocate fields for cover crops and maintain the biomass over a long time to improve soil fertility.

Low awareness of benefits

Low awareness of conservation agriculture benefits delayed adoption and investment. Information and knowledge flow and local networking need to be improved.

Institutional challenge

Local implement manufacturers appear to be more responsive to farmers and facilitate product development. Local manufacturing needs support. User groups need help to purchase conservation agriculture equipment.

11 Conclusions

- **Rigid conservation agriculture packages**, which prescribed using the contact herbicide Gramoxone to manage weeds, **delayed the adoption of conservation agriculture** in Wanging'ombe, Njombe District. Compromise technical substitutions that do not subscribe fully to conservation agriculture principles but are more accessible are a better alternative.
- **Conservation agriculture stakeholders were poorly linked.** Sharing experiences was restricted to individuals. Likewise, collecting, processing, storing and retrieving information in the division and district was poor. Information flow, knowledge management and local networking needed to improve. Smooth transitions from one project to another should be facilitated.
- With exception of the TARP II, Sokoine University of Agriculture, FAO and FARM Africa projects, **conservation agriculture projects in the case study area were either underfunded below 20% of budget or operated for short periods,** one to two years. Such projects classically withdraw, unceremoniously and prematurely, leaving their partners and beneficiaries in limbo. Straining the farmer, researcher and extension trust spoils future interventions and squanders meagre resources.
- It is preferable to ascertain at project planning the funds available to choose a **low money approach, with a longer time frame, or high money, with results in less time.** District councils need to be involved and commit funds for research and promotion.
- **Farmer field schools are an efficient and cost-effective approach for evaluating and promoting conservation agriculture.** Group cohesion and sharing group ideals are essential for a farmer field school to succeed. The field schools should not target individual spouses, but both husband and wife. Adolescent boys and girls need to be involved if they farm.
- District and village extension workers have limited access to information and practical training on conservation agriculture and suitable practices. **Conservation agriculture initiatives have provided learning for all involved**—farmers, extension officers and implement manufacturers.
- **Understanding the techniques and appreciating conservation agriculture benefits are more important than access to resources for smallholder farmers**.
- **Vegetative soil cover is jeopardized by indifference, bush fires and free-range cattle** from neighbouring villages or on stock routes. This must be tackled by wards or divisions rather than the village.
- **Conservation agriculture is a viable and profitable labour-saving technology** for the Njombe and Mbeya District farmers. However, farmer crop yields were much lower than those on station. This was attributed to farmers using little or no fertilizer and poor access to implements because of cost.

12 Recommendations

- While some benefit of conservation agriculture can be obtained in one to two years, full realization requires four to five years. **Interventions need to have adequate time to support farmers until a critical mass of adopters has been attained.** Sustainability should be built in all conservation agriculture projects to ensure continuity after the official end of the project. From the beginning, the project should seek local NGO and district government involvement and commitment to continue project services after the project ends.
- **The knowledge and culture of managing information in districts needs to be cultivated** to identify strong or weak conservation agriculture techniques and exchange information among all conservation agriculture participants.
- Farmers, extension workers, agricultural NGOs and manufacturers **can benefit from additional knowledge and training** in conservation agriculture to spread the knowledge beyond researchers.
- Conservation agriculture benefits should be promoted to more policymakers, service providers and beneficiaries, possibly through field days, field demonstrations, workshops and radio and television advertisements. **Clear and simple messages on conservation agriculture need to be developed** to train and support extension officers and farmers.
- **Farmers need help in acquiring relatively high-cost implements and supplies** for conservation agriculture to accelerate adoption. Providing credit to farmer groups using group peer pressure as collateral, subsidies for women groups and empowering savings and credit cooperative societies to provide credit to members are some recommended alternatives.
- **Awareness campaigns or passing bylaws** to prevent free-range grazing and bush fires, to maintain soil cover, should be done by divisions and should involve as many stakeholders as possible.

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Appendix 1 Selected farmer profiles: no. 1–8 interviewed from Mayale, no. 9 from Wanging'ombe village

No.	Farmer name	M/F	Age (yrs)	Family size	Land owned (acres)	Livestock	Implements	Crops grown and acreage	CA practices	Benefits, yields under CA (kg/acre)	Projections and future ambitions	Challenges
1	Hamida Mussa	F	43	9	6	1 ox 2 work cows 2 calves 4 goats 4 chickens	1 cultivator 1 ripper (on credit)	maize/cow peas 3 sunflower 1.5 groundnuts crotalaria sole 0.5	ripping by cows crotalaria for soil fertility and cover	maize: 250 (compared with 70 for neighbour)	Change cover crop from crotalaria to mucuna—higher grain yields and better soil cover Seek assistance for fertilizers Plant green grams	Fertilizers are a problem Long sickness of father from bicycle accident
2	Bilet Nginybudzi	F	38	5	10	26 goats 4 oxen	1 ripper (on credit)	maize 3 sunflower + cowpea 4 popcorn, cowpea 3	acquired ox ripper but not used yet		Has learned from FFS on use of basal fertilizers	Prolonged sickness of husband
3	Hajira Omari Mllonganile	F	—	10	11 (7 bought this year at TZS 15,000)	5 cows 10 goats chickens	2 ploughs 1 ridger 1 cultivator 2 bicycles 1 cart	maize 2 sunflower + cowpea 3 groundnuts 1 popcorn (rented) 2 mucuna 0.5	ripping mucuna (sole) for soil cover and fertility	maize 600 sunflower 200 pop corn 400 goundnuts (shelled) 180 mucuna 280	Add one cultivator Add one ripper bottom Prefers mucuna. Good yield even in sandy soils Plan to construct another house Increase livestock by 2 more oxen	Cowpeas in sunflower are a problem when ox weeding; need physical removal

No.	Farmer name	M/F	Age (yrs)	Family size	Land owned (acres)	Livestock	Implements	Crops grown and acreage	CA practices	Benefits, yields under CA (kg/acre)	Projections and future ambitions	Challenges
4	Ramla Mustapha	F	—	4	7	1 ox 1 cow (not used for traction)	1 plough 1 cultivator (on credit)	maize 2.5 (no fertilizer, no 2nd weeding) sunflower 4 popcorn 0.5	ripping sole lablab for soil cover, fertility	maize 480 sunflower 190	Ripper saves time, allows timely fire-wood collection and meal preparation Change lablab to mucuna	Lablab attacked by field pests, poor yields
5	Gaudensia Mligo	F	—		20 (all bought in 2004 at TZS 40,000)			maize 2.5 groundnuts 1	researched on ripping, ripper-planting, ridging and tied ridging	poor rainfall; maize yields: ploughing 400 ripper-planter 540 tied ridges 540 ripping 700	Change lablab to mucuna Increase maize acreage Increase groundnuts 1 to 5 acres	
6	Esther Chambulikazi	F	—	7	5 (2 acres bought in 2005 at TZS 12,000)	3 oxen 7 cows 3 calves 15 chickens	1 plough 1 cultivator 1 ripper (on credit)	maize 2 sunflower + cowpea 1 mucuna 0.5	ripping + manure application on furrow sole mucuna to fertilizer and cover soil	maize 1350 sunflower 350 cowpea 220 mucuna 40	1 acre to be used for forage trees Acquire another cultivator	Fertilizer for topdressing not accessible. Only farmyard manure used

No.	Farmer name	M/F	Age (yrs)	Family size	Land owned (acres)	Livestock	Implements	Crops grown and acreage	CA practices	Benefits, yields under CA (kg/ acre)	Projections and future ambitions	Challenges
7	Sikudhani Ramadhani	F	—	5	4	2 oxen 2 cows 7 goats 4 sheep	ridger plough cultivator (on credit) ripper	maize 4 mucuna 0.5	ripping sole mucuna	maize 800	Split mucuna plot to plant mucuna + maize Plant other crops like sunflower, bambara nuts and groundnuts	Oxen power not adequate
8	Daniel Lugenge	M	—	6	5	2 cows 2 calves 4 sheep goats	ripper plough	maize 2 sunflower 1 fallow 2	ripping cover crops	yield increased from 300 to 1300	Plant large areas of mucuna, tephrosia, lablab for cover Trained father on ox weeding; he purchased cultivator to replace hand hoe weeding labour at TZS 6000–7000 per acre	Weeding is the threat; no guarantee to have oxen for weeding
9	Ekati Mtekele	M	—	8	7	6 oxen 10 cows 2 goats chickens	plough	maize + beans 2.5 sunflower + cowpea 1.5 grass fallow 2	trained in CA: jab, direct seeder, ripping	not practising any, 4 years after	—	—

Appendix 2 Village households and population in Wanging'ombe and Mshewe Wards

No.	Wanging'ombe Ward			Mshewe Ward		
	Villages	Households (no.)	Population	Villages	Households (no.)	Population
1	Wanging'ombe	539	2274	Mshewe	367	1877
2	Utiga	546	2304	Muvwa	417	1730
3	Mayale	532	1405	Njelenje	338	1636
4	Lyadebwe	404	1707	Mapogoro	206	709
5	Itandula	197	839	Mjele	389	1714
6	Kijombe	446	1884	Ipwizi	90	676
7	Ukomola	207	880	Chang'ombe	128	651
8	Lyamluki	293	1241	Ilota	212	870
9	Ufwala	215	915			
10	Ikwavila	172	734			
11	Munyelenge	447	1885			
12	Katenge	597	2519			
Total	12	4595	18587	8	2147	9863

Appendix 3 Intervention details

Initial conservation agriculture approaches by ARI Uyole (1998–2003)

Animal-powered ridging, tied ridging, ripping and ploughing were compared on-farm in trial plots for a farmer research group in Wanging'ombe. Each of the 12 farmers in the research group managed four subplots, 9.75 x 30 m. Tilling was started two weeks before expected rainfall. Planting was done before or with onset of rainfall. Weeds were managed using the ridger in ridged plots, the tie ridger in tied ridge plots, contact herbicide (Gramoxone) in ripped plots and the hand hoe in the ploughed plots. These practices were repeated for the second weeding—except that herbicide was replaced with ox ploughing. Cover crops and soil cover were not considered. In the years that followed, ridges and ripped planting furrows were maintained, no ridges were split.

Farmers contributed land, oxen and labour, while ARI Uyole supplied a test implement set for each group, improved seeds, fertilizers, herbicides and technical support. The two village extension officers in Wanging'ombe Ward, which has 12 villages, constantly supervised the research trials and facilitated group organization.

Farmer research group members were guided in evaluating and ranking the farm tools. They were then encouraged to choose technology for scaling up. Field days involving other villagers and outsiders were held before harvest.

Conservation agriculture technology introduced under NAEP (2001)

Conservation agriculture initiatives by the National Agricultural Extension Project (NAEP) for the Soil Fertility Recapitalization and Agricultural Intensification Project (SOFRAIP) were implemented by the Mbeya District agricultural extension officer in Njelenje and Mshewe and involved 40 farmers in 2001. They used ripping with oxen and the herbicide Round-Up applied two weeks before planting. Fertilizers and seeds, enough for 0.5 ha for each farmer, were provided on credit and as a basis for a revolving loan fund.

Decentralized decisions provided leeway for some farmers to replace Round-Up with fertilizers, and conventional ploughing was substituted for ripping. Farmers were familiar with the dramatic results of chemical fertilizers as opposed to Round-Up or long-term soil conserving measures. Cover crops were not included and researchers were not involved.

Rippers were purchased from SEAZ and fertilizers and herbicides were distributed by Tanzania Fertilizer Company and Tanganyika Farmers Company of Mbeya city and, to a limited extent, by local dealers.

For Mbeya region, this pilot project was also implemented by Mbozi and Mbarali Districts, with several conservation agriculture combinations. For example, Mbarali District introduced comparisons of planting systems with cover crops: mucuna or maize intercropped with mucuna and maize. The initiative lasted only one season and no attempt was made to recover loans provided to farmers for the supplies. This set a bad precedent for recovering future loans.

Conservation agriculture technology promoted by TARP II SUA

Initiatives under TARP II SUA in 2001 considered soil and water conserving structures with no cover crops but did away with herbicides. The new villages targeted by the intervention were Kisilo and Mayale in Njombe District, and Matai, Nkundi and Sandulula in Sumbawanga District in Rukwa.

Conservation agriculture technology introduced by SFI

When the Soil Fertility Initiative (SFI) was introduced in 2001, new villages and new farmer groups were added in Wanging'ombe village to evaluate 'new and improved' conservation agriculture using cover crops, agroforestry and amelioration of hardpans (table 4). The trials were initiated by ARI Uyole but were implemented with close involvement of socio-economic researchers and the village extension agents.

Of the two new farmer research groups in Wanging'ombe, the first with five farmers including two women, evaluated hardpan amelioration techniques:

- deep ripping, two passes on the same furrow, with ripper
- cover crop 1, *Cajanus cajan* (pigeon pea)
- cover crop 2, *Lablab purpureus* (lablab)
- ox ploughing, conventional shallow (13–16 cm deep)

Plots measured 9.75 m by 30 m. All farmers tested all four techniques. All farmers intercropped maize with pigeon pea and with lablab. Time and labour, cover crop root development in a 0.5-m^2 quadrant, soil moisture in a 14-day interval, and maize yield were measured.

The second farmer research group had six participants, including three women. They evaluated zero and reduced tillage implements, cover crops, crop rotations and maximum soil cover:

- jab planter, followed by two hand hoe weedings
- ripping, first weeding by ox cultivator, sowing pigeon pea under crop, second weeding by hand pulling and hoeing
- direct seeder, first weeding by ox cultivator, sowing lablab under crop, second weeding by hand pulling and hoeing
- conventional ox ploughing, followed by planting with rope and hand hoe, two weedings by hand hoe

Farmers could choose from mucuna, labbab, canavalia and *Crotalaria ochroleuca* for cover crops. Treatment plots were 9.75 x 30 m. Maize was chosen as the test crop. Farmers contributed oxen, land, labour and time for training sessions. Researchers supplied test implements, cover crop, and maize seeds and fertilizers, while extension personnel provided crop husbandry and group cohesion advice.

At Kanamalenga village, three farmers evaluated the ameliorations of hardpans. Eight other farmers participated in the tillage technique and cover crop trial. The farmer group in Mapogoro village had 8 participants and Njelenje village had 10 in the tillage and cover crop trial.

Conservation agriculture technology promoted by TCP/URT/3002 (2004–2006)

In the TCP/URT/3002 project in Mbeya District, supported by MAFS and FAO, 10 farmer groups from nine villages participated, each with 25 farmers. The comprehensive conservation agriculture package included cover crops, maximum soil cover, crop rotations, and zero and reduced tillage with jab planter, direct seeding or ripping. Each farmer had a one-acre plot, with conservation agriculture practised on one-half and conventional cultivation on the other half.

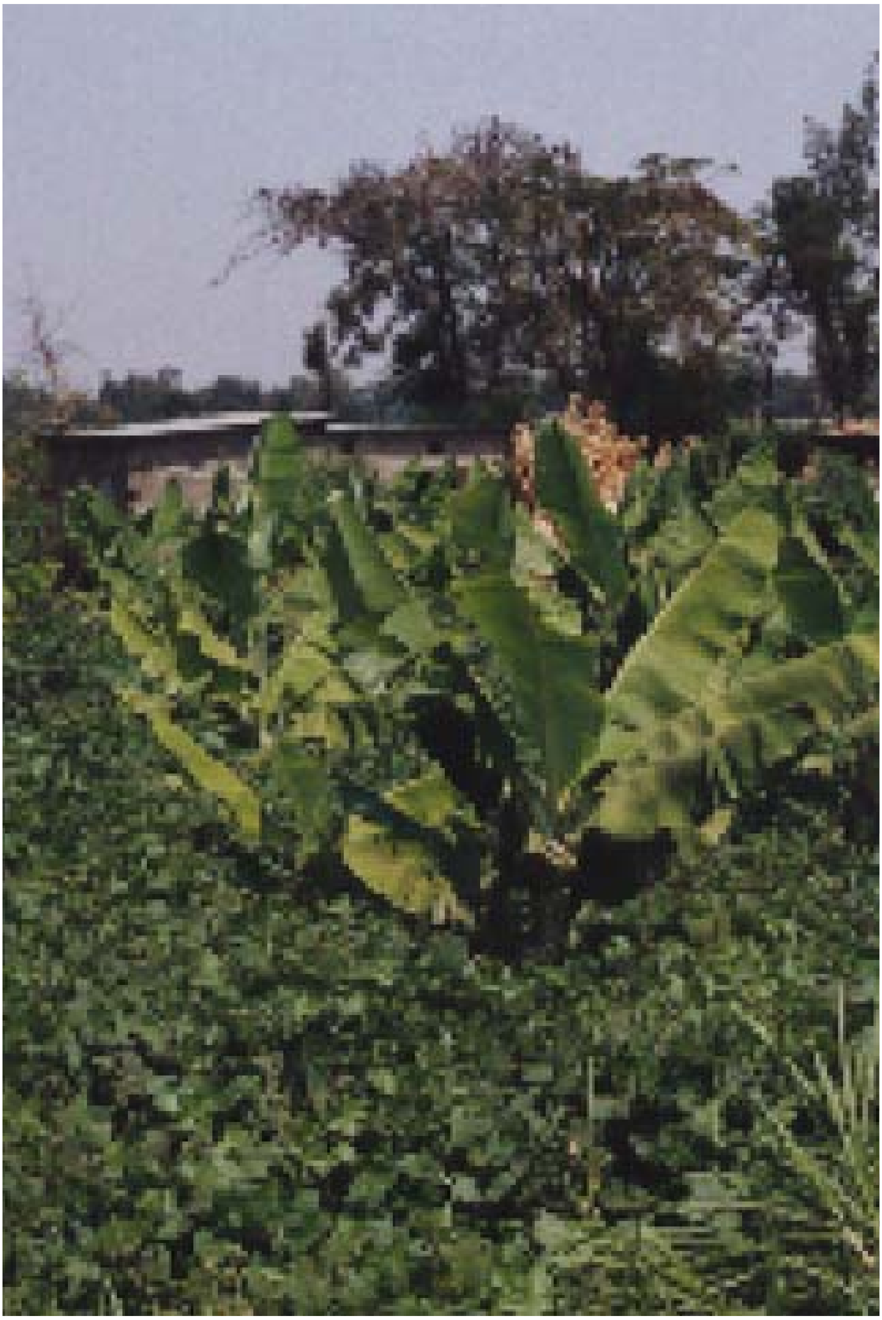
The Technical Cooperation Project contributed implements, cover crop seeds, herbicides and fertilizers. Farmers contributed land, labour, oxen and time to be trained and for training others. Other partners were the Mbeya District Executive Director, whose extension staff provided the agricultural extension services, and an ARI Uyole researcher who provided technical support. SEAZ supplied rippers, but jab planters, direct seeders and prototype animal-drawn knife-—rollers were imported from Fitarelli, a manufacturer in Brazil.

Contours established for soil conservation in Sakila

Banana with crop residue as mulch

Land degradation due to soil erosion

Women in Karatu carrying their produce to market in the tradtional way



Banana crop with mucuna as a cover crop

Effect of free grazing on soil cover

Because the weeds on Mama Mchome's farm were overwhelming, the family inverted the soil as well as ripping it

Types of soil cover: lablab plus maize residue after harvesting maize

Maize residue as soil cover

Intercrop of maize with pigeon pea. The tops of the maize plants have been cut

The dense canopy formed by pigeon pea after harvesting maize

The pigeon pea crop has been left on the field for another season

Pigeon pea intercropped with maize

Demonstrating conservation agriculture implements

Farmers in Wanging'ombe village evaluating an ox-drawn direct seeder

Transferring crop residue for livestock feeding becomes a major source of conflict when trying to keep the soil covered for adequate maintenance